

Table of contents

PART 1: Karst

Landscapes and Caves

Overview and fundamentals	4
Illustrated record of life forms	5
Geology	6
Hydrology	11
Physical Geography	13
Cave Biology	15
Paleontology and Archaeology	21
Safety in the Caves	28
Conservation in the Caves	31
Map of El Capitan Cave	36
Bibliography	37
Glossary	39
Map of Karst Areas in Southeast Alaska	44
Educational Activities	46-67

PART 2: Paleontology

El Capitan Management Plan	68-116
Geological Time Scale . .	118
Map of fossils finds in the region	119
Top 12 Fossils of Southeast Alaska	120-131



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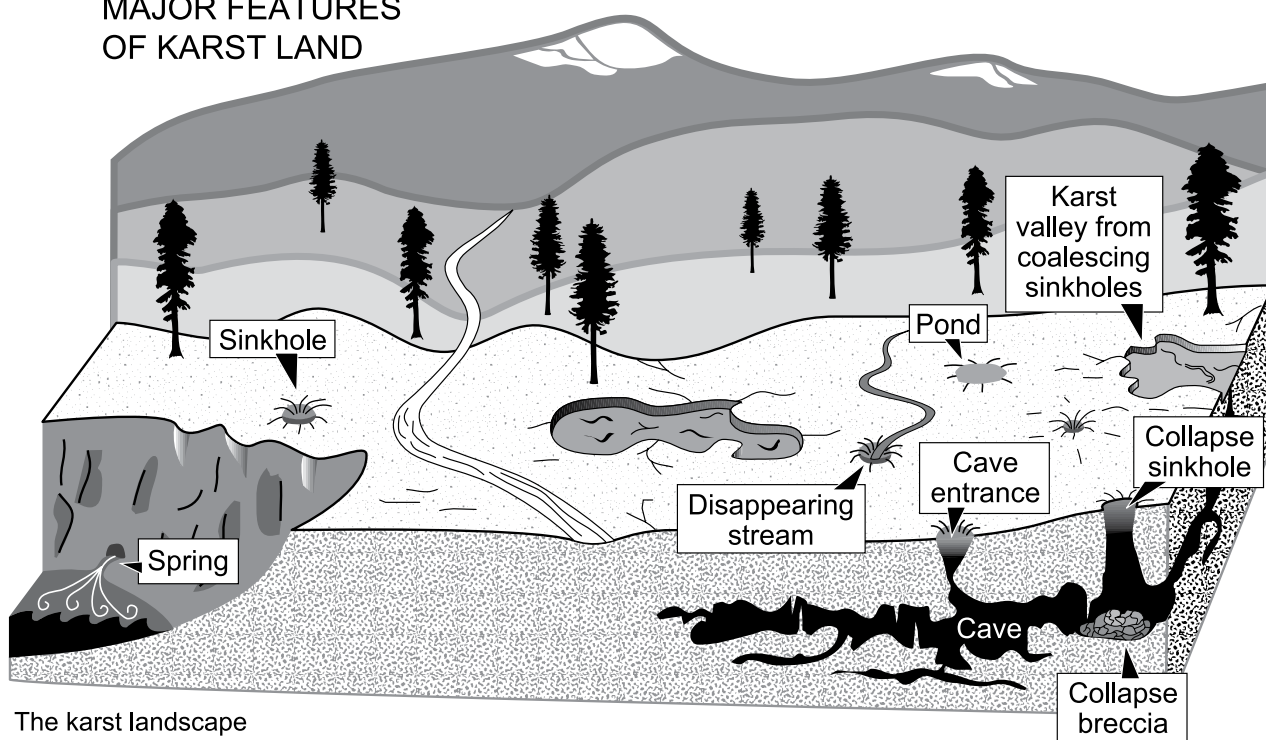
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Anatomy of a landscape

MAJOR FEATURES OF KARST LAND



The karst landscape is a dynamic and changeable place. Its features are rarely as obvious as our diagram suggests, and you don't find all of them together this neatly. However, the diagram offers a guide to the most typical physical traits of the landscape we'll discover in this book on the karst lands and caves of Southeast Alaska.

INTRODUCTION

This resource guide was prepared for middle-school and secondary-school teachers as a source of information and ideas about the caves and karst lands of Southeast Alaska. We include in the binder a map depicting the karst lands and geology of Southeast Alaska; a descriptive guide with glossary and student activities; goals and objectives for activities; and useful appendices.

Another good overview of caves and karst lands was produced by the American Cave Conservation Association. *Learning to Live With Caves and Karst* includes excellent teaching activities and resources. Send your request to:

American Cave Conservation Association
P.O. Box 409
Horse Cave, KY 42749

Project Underground is also a good source of information on caves and karst landscapes. Their contacts:

Project Underground
8 Radford St.
Christiansburg, VA 24073
540-394-2553
www.projectunderground.org

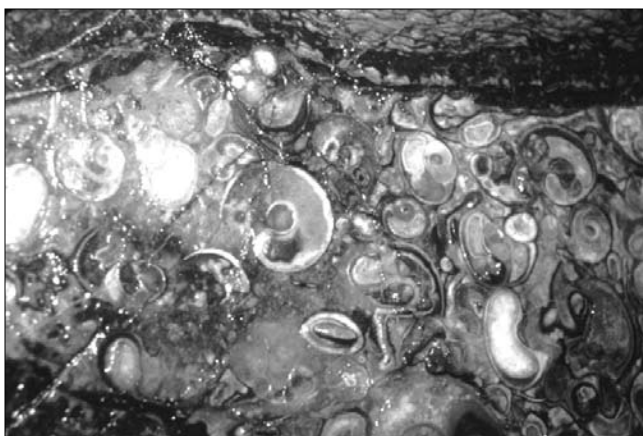
This guide together with the publications from American Cave Conservation Association and Project Underground provide a comprehensive discussion of the topic as well as information specific to our own Alaskan caves.

GLOSSARY ITEMS

When you come across words and terms printed in italicized small capital letters (e.g., *SINKHOLES*), refer to the glossary starting at page 37 to learn more.

Why we have karst land features in Southeast Alaska: it's a combination ...

- Pure carbonate bedrock
- Bedrock contortions: faulting , fracturing, folding
- Intrusions of igneous rock
- Local tectonic events
- Glacial history
- Proximity of carbonates to peatlands and forest vegetation
- Abundant precipitation
- Moderate temperatures



Well-traveled fossils—*Marine invertebrates that died near the equator in the Silurian period 400 million years ago are now embedded in limestone on Heceta Island along northwest of Prince of Wales Island.*

“Karst” — a name that came from the Balkans

The adjective used for this geological feature derives from *Kras*, an area of Croatia near the coast of the Adriatic Sea. Some of the earliest research on karst landscapes was conducted in that Balkan region.

THE KARST LANDSCAPE AND CAVES OF SOUTHEAST ALASKA

Some of Alaska’s most impressive natural and scientific wonders are out of sight.

The fascinating underground world of Southeast Alaskan caves has remained out of sight for thousands of years — known only to uniquely adapted cave creatures and visiting bears, otters and humans.

Only in recent years have scientists and other explorers pushed into the region’s intricate systems of subterranean karst features, mapping the geological and biological resources of the caves.

An overview of the underground

This resource guide provides you with a broad perspective on karst landscapes and caves. We look at the origins of Southeast Alaska’s karst features. We see the geological and chemical processes that sculpt them. These pages survey the process of limestone dissolution and review the creatures that inhabit and visit the caves, and how their remains tell scientists more about the ancient past in this area. This book also offers a guide to conserving this precious natural world while safely visiting it.

First, fundamentals: What is karst?

Karst landscape **is** composed of bedrock that can be dissolved by water. This geological feature is more common in the continental United States than in Alaska. In fact, temperate rain forest karst landforms are unique to Southeast Alaska.

About 20 percent of the earth’s surface is karst geology. It’s common in the southern continental United States, in California and in British Columbia: for example, 40 percent of the lands east of Tulsa, Okla., are karst landscapes. Karst geology is also found in southern Asia, in Indonesia, in Tasmania, in New Zealand and, in Europe, in the Balkans—the region that gives this landform its name (see sidebar).

LIFE and the fossil record

.01 MILLION
to PRESENT

► **Holocene**



Modern humans appear only in the past 100,000 years

2-.01
MILLION

► **Pleistocene**



The genus homo

5-2
MILLION

► **Pliocene**



First hominids

23-5
MILLION

► **Miocene**



Early apes

34-23
MILLION

► **Oligocene**



First bats

First whales

55-34
MILLION

► **Eocene**



First primates

Mammals flourish

65-55
MILLION

► **Paleocene**



Gymnosperms decline

141-65
MILLION

► **Cretaceous**



Angiosperms (plants with flowers) radiate

202-141
MILLION

► **Jurassic**

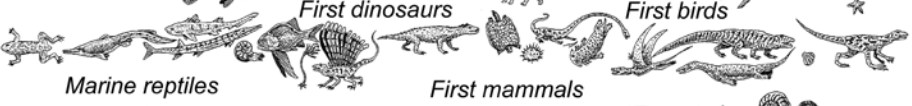


First dinosaurs

First birds

250-202
MILLION

► **Triassic**



Marine reptiles

First mammals

290-250
MILLION

► **Permian**



Gymnosperms (plants with cones) dominate

First reptiles

363-290
MILLION

► **Carboniferous**



First insects

Vertebrates come ashore: amphibians

409-363
MILLION

► **Devonian**



First plants with seeds

First jawed fishes

439-409
MILLION

► **Silurian**



Early land plants

First fish

510-439
MILLION

► **Ordovician**



Diverse marine invertebrates

Complex animals

Early chordates

544-510
MILLION

► **Cambrian**

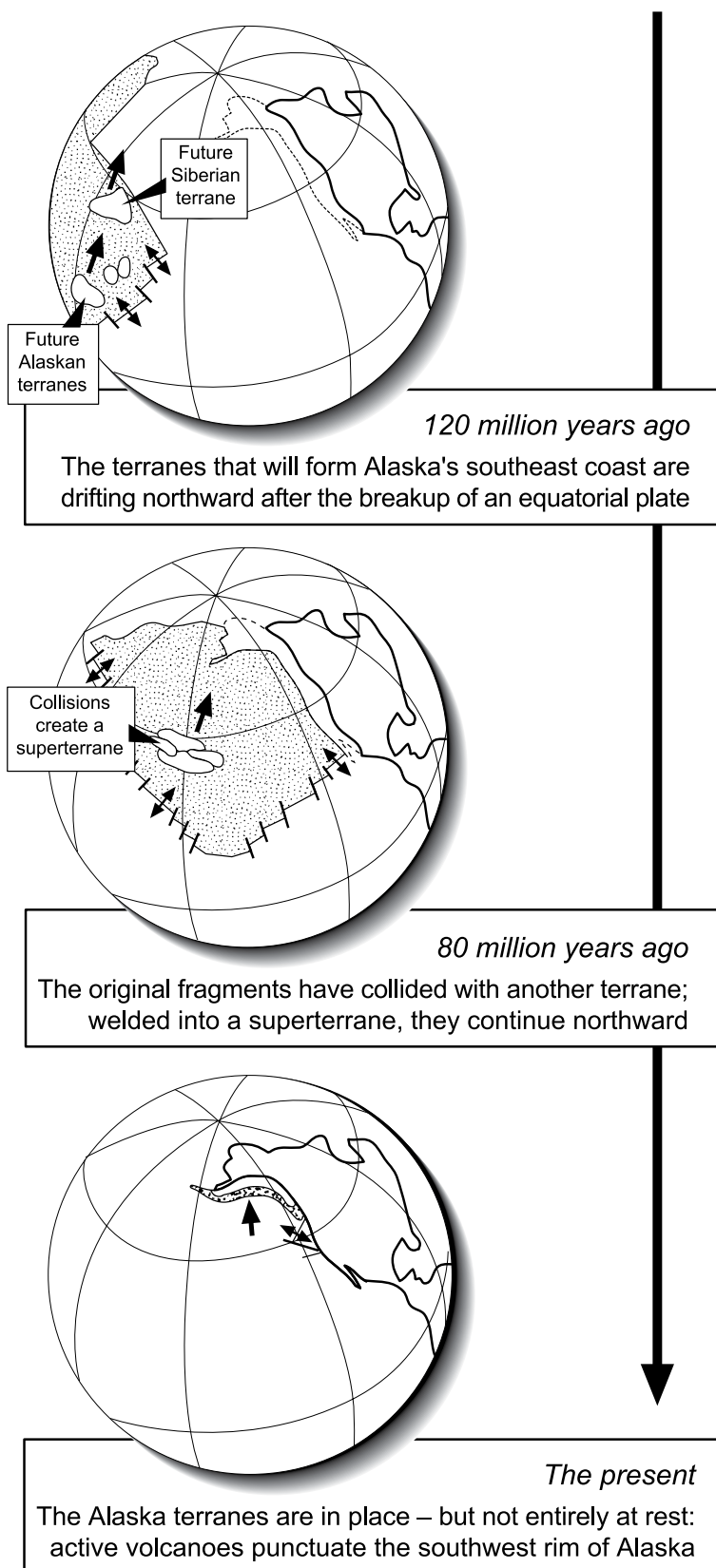
Years ago

► **Period**

► **Epoch**

Artwork by Ray Troll © Ray Troll 1994

Alaska's coast: how it got here



Adapted from Stone, Panuska and Packer (1982)

GEOLOGY

Karst landscapes in Southeast Alaska, like other karst areas around the world, are characterized by surface features we can easily see, such as *SINKHOLES* and disappearing streams. They are also places of subsurface wonders, such as underground streams and cave systems. Interaction of soluble bedrock — usually *LIMESTONE* — and acidic surface water produces these unusual features.

Alaskan landscape made in the South Pacific

The story of the karst landscapes of Southeast Alaska begins with the formation of its carbonates in the South Pacific during the Silurian Period, 438 million to 408 million years ago. Warm, shallow equatorial waters teemed with *CYANOBACTERIA*, plankton, algae and numerous kinds of invertebrates. Many of these organisms took dissolved *CALCITE* from the water to build shells, external skeletons and other hard body parts. When they died, soft body parts deteriorated and hard parts drifted to the ocean floor. Mats of photosynthetic bacteria and sediments trapped in them accumulated as *STROMATOLITES*. These reef formations also shed fragments. Over time, huge calcite deposits were transformed into limestone by compaction and cementation.

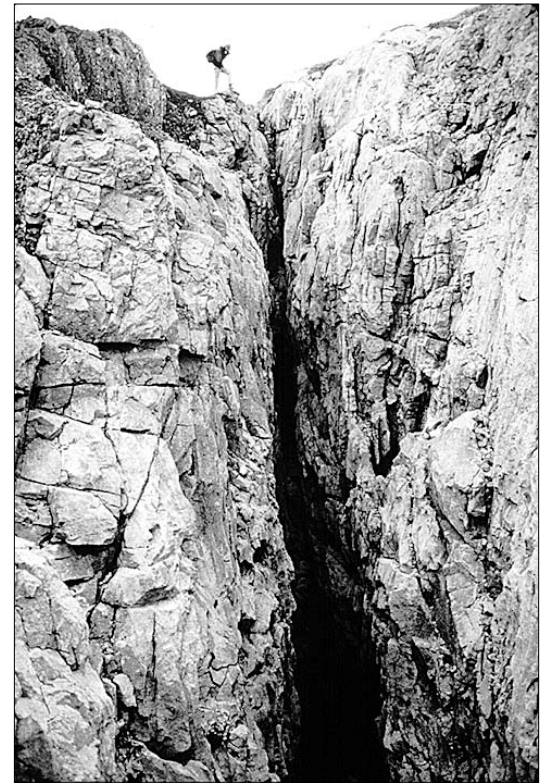
North to Alaska: migration of South Pacific land

About 400 million years ago, our continental fragment and others began riding northeast on the slow-moving Pacific *TECTONIC PLATE*. Some

fragments collided with other continental pieces and joined in a large microplate as they drifted thousands of miles northward. This microplate and other fragments “docked” with the northern coast of North America between 150 million and 100 million years ago. The oblique collisions smeared the fragments along the coast, like multiple icings applied haphazardly to the side of a cake. After the collision with the North American continental mass, the fragments continued their northern migration, leaving bits and pieces behind. The forces that keep these fragments in motion have folded, fractured, and sheared the bedrock. Because these fragments traveled great distances to their new geologic home, they are called *EXOTIC TERRANES*. Southeast Alaska is a mosaic of at least 11 different terranes. Each has a distinct geologic character, range of ages, sites and characteristics of origin.

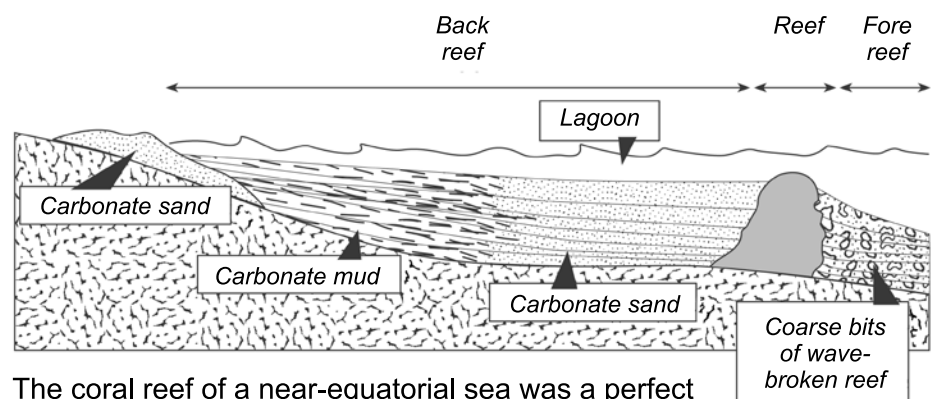
The wandering Alexander terrane comes to rest as Southeast Alaska

The Alexander terrane is the principal terrane of Southeast Alaska. Carbonates record the terrane’s wandering from its origins during the Silurian Period. These carbonates contain massive limestones of three distinct types: fore reef deposits; reef deposits; and back reef deposits of thin, wavy-bedded, fossil-rich limestone. The heat and pressure of extreme collisions and forces of plate tectonics caused a metamorphosis of some of the limestone into marble during certain *DOCKING* events. When the Alexander terrane collided with the ancient shore of southeast Alaska, it was spectacularly fractured and then fragmented. The force of the collision made large strike-slip faults, oriented north-west-southeast. Smaller strike-slip faults oriented north-south intersected



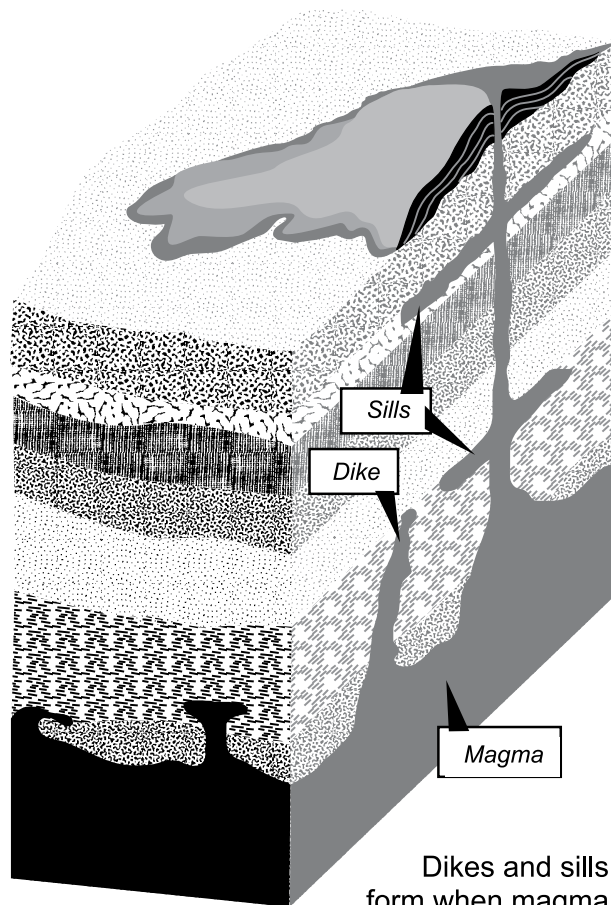
The karst landscapes of Southeast Alaska tell stories tens of millions of years old — tales of plate tectonics and chemical processes

Ancient seas: limestone factories



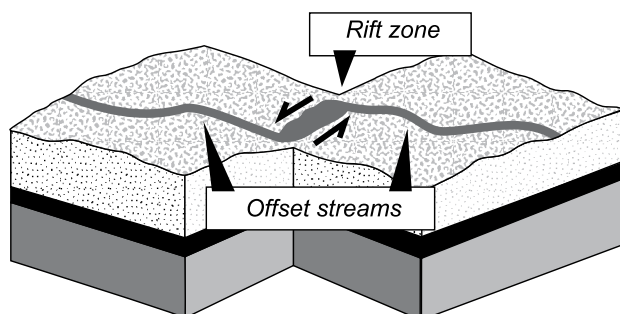
The coral reef of a near-equatorial sea was a perfect calcium carbonate production area in the Silurian Period. Such sites and the sea bottom in deeper areas gathered the organically produced minerals that moved thousands of miles to Alaska and became part of our karst landscape.

Formations from fiery rock



Dikes and sills form when magma invades subsurface rock. Vertical igneous intrusions are dikes; horizontal igneous intrusions are sills.

Faults with shear power



Strike-slip faults occur with horizontal movement of blocks on opposite sides of a fault plane. These shearing forces were commonplace as the Alexander terrane took its present place along the coast.

these and broke the terrane into huge blocks. Thus, terrane blocks bounded by the large faults are in turn broken into smaller blocks by small faults; these small faults mimic the pattern of their larger counterparts. The same fault pattern can be seen at all scales of magnitude, from terrane boundaries to outcrops and specimens you can hold in your hand. The large-scale faults — as big as islands or mountains — help to define karst system boundaries in Southeast Alaska.

About 632,000 acres (988 square miles) of carbonate rock have been mapped throughout Southeast Alaska. Southern Southeast Alaskan carbonates are especially pure, averaging more than 96 percent calcite. These carbonate formations provide soluble bedrock that is fundamental in the karst landscape. Limestone and marble in karst areas are dissolved or chemically weathered by abundant acidic surface waters.

Surface waters follow fractures, faults and folds in the carbonates, sculpting both the surface of the karst and dissolving cave systems below. Igneous intrusions such as dikes and sills also provide sites of structural weakness in the bedrock where solution features can develop. Surface waters in Southeast Alaska are acidic due to carbonic acid in rainwater and organic acids in runoff through forest soils and peatlands. Recharge areas, which supply water to karst systems, may lie on carbonate rock or on non-carbonate *SUBSTRATES*, such as conglomerates, sandstones, or volcanic rocks.

Karst landscapes have existed in Southeast Alaska for a long geologic time and have been impacted by *GLACIERS*. For example, passages in two different caves on Prince of Wales Island are found through what may be Tertiary (65 million to 2.5 million years ago) *PALEOKARST BRECCIAS*. These findings suggest that caves have been forming in the carbonate for a long period. Most caves predate the latest glacial

advance, which reached its maximum extent between 22,000 and 17,000 years ago. At that time the vast Cordilleran ice sheet covered most of the landscape, although it is likely that some ice-free *REFUGIA* remained at high elevations and along the coast. The inferred ages of the caves are based on the presence of glacial clays, glacial sediments, wood, *VERTEBRATE* remains from the late Pleistocene (2.5 million to 10,000 years ago) and possibly even ancient ice. One small cave has yielded a *MARMOT* tooth which has been dated to more than 44,500 years ago. The remains of a black bear more than 41,000 years old and a brown bear 35,300 years old have been found in another cave. Similar features have been found in field reconnaissance on Kuiu and Chichagof islands and on islands seaward of Prince of Wales Island. Such evidence clearly suggests that glaciation modified a pre-existing karst landscape. Glacial activity collapsed certain cave passages and systems, gouged into others, and filled some with sediments. Features of the *EPIKARST* were also influenced by glaciers.

Epikarst is the highly dissolved karst connection zone that links the surface to the subsurface. Vertical fractures in the epikarst are conduits between upper areas and cave systems below. The extent of epikarst development in Southeast Alaska is linked to the glacial history of the land, the elevation, and other factors. Epikarst is well-developed throughout the karst areas of Southeast Alaska, but is exceptionally pronounced at higher elevations (above 1,800 feet), where the most recent glaciation has not removed deep and elaborate epikarst features. Epikarst in alpine areas is less vegetated and is characterized by deep shafts, crevasse-like fissures, eroded rills of all sizes and spires and spikes of carbonate rock. Below treeline, epikarst is more vegetated and shallower. Epikarst in the alpine zone may be more than 100 feet deep, compared to less than 5 feet along the coast and at lower elevations. Epikarst at all elevations is very important in moving water, inorganic nutrients, organic matter and soil from the



Typical epikarst is impressively on display on an alpine mountaintop in Southeast Alaska.



Thin soil lies atop low-lying epikarst.

Explorations continue

Hundreds or even thousands of yet-unexplored caves exist in Southeast karst areas. El Capitan Cave is the longest cave discovered so far, with 12,000 feet of surveyed passages and a depth of 256 feet.

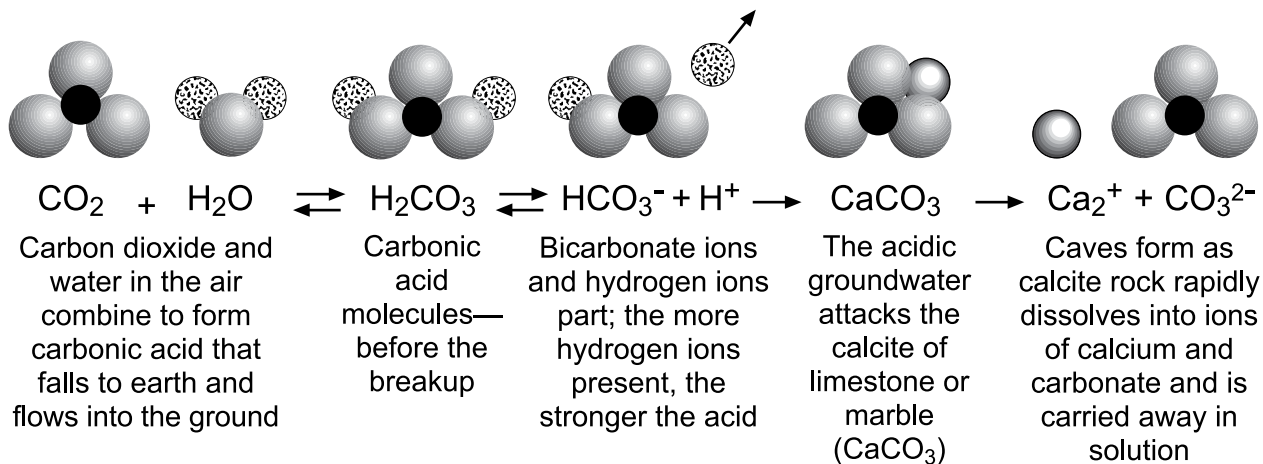
Caves can keep secrets of glacial times

Most caves predate the latest glacial advance, which reached its maximum extent between 22,000 and 17,000 years ago. Because of this, we can use the caves to look at ancient life.

KARST CHEMISTRY

The calcite equation

 Oxygen
  Carbon
  Hydrogen
  Calcium



The 96 percent solution

Southern Southeast Alaskan carbonates are especially pure and provide soluble bedrock for the karst landscape. Acidic surface waters focus on fractures, folds, or other weaknesses in the carbonates, sculpting both the surface of the karst and dissolving out cave systems below.

land surface and rooting zone into subsurface regions. From subsurface areas, these materials move laterally to seeps and springs, or to vertical collecting structures which channel materials down to caves.

Hundreds or even thousands of caves in Southeast karst landscapes are still unexplored. They typically have vertical entrances and shafts that open to networks of cave passages. Huge volumes of groundwater surge periodically or continually through the passages. Scalloped walls and ceilings, spiral passages, deep plunge pools, flooded passages and sumps are common features. Boulders more than 2 feet in diameter seasonally batter the walls of some cave passages.

HYDROLOGY

Hydrology is the study of the properties and effects of water on the earth's surface, in the soil, in underlying rocks and in the atmosphere. Karst caves are dramatic examples of the action of acidic groundwater on soluble bedrock. Karst is formed primarily by chemical weathering of rock, rather than by mechanical weathering.

Carbonic acid occurs naturally in the ample rainfall of southeast Alaska due to the combination of atmospheric carbon dioxide and water. Organic matter in the soil also produces carbon dioxide, which reacts with water percolating through the soil to form more carbonic acid. Another source of acidity in the **GROUNDWATER** is organic acids, common components in the soils of coniferous forests and peatlands. The resulting acidic groundwater dissolves calcite in limestone and marble into its constituent ions, such as calcium and carbonate ions. The dissolved ions remain in solution and are then carried away in surface water and groundwater. A complex network of vertical shafts and lateral cave systems develops over time as the carbonate rock dissolves along joints and bedding planes.

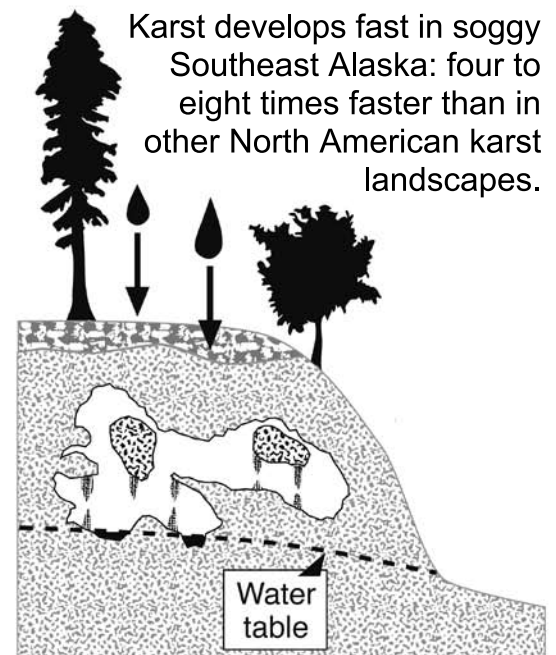
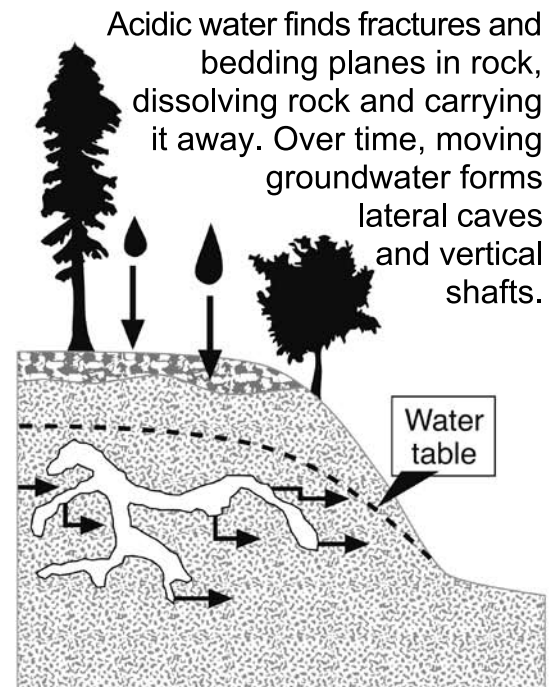
Speleothems: unique, natural works of art

Deposits of calcite form in caves when the mineral precipitates from the groundwater onto the cave's ceiling, walls or floor. Because hydrologic activity is intense in the caves of Southeast Alaska, dripstone deposits, or **SPELEOTHEMS**, are not as plentiful as in other areas. But some striking formations of flowstone and delicate structures of **HELICTITES** and **SODA STRAWS** can be observed. Another speleothem, called **MOON MILK**, forms in deposits several feet thick — unusual for this type of formation.

Waters in surface peat are particularly important contributors to karst topography and caves in Southeast Alaska. Peatlands occur around the world and have a variety of common names, such as fens or bogs. Here in Southeast Alaska they are called muskegs. They are always characterized by

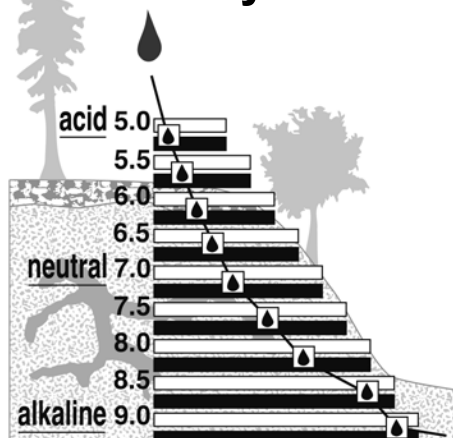
SPELEOGENESIS

Creation of caves in karst landscapes



pH

Karst landscape chemistry



The flow from muskegs is acidic—in some areas, with a pH value as low as 2.4. Rainwater is also acidic. But the karst process chemically changes the water as it flows through calcite rock. Outflows from karst landscapes commonly have pH values of 7.5 to 8.0.

pH

A solution's pH number is its measure of acidity or alkalinity. A neutral solution has a pH of 7. Greater numbers indicate relative alkalinity; lesser numbers indicate relative acidity. The chemical shorthand comes from "p(otential) of H(ydrogen)."

waterlogged, acidic soils. In this region, peatlands develop on two types of sites: atop poorly drained, non-carbonate rocks, or on top of impermeable, compact glacial tills and marine silts that lie above non-carbonate or carbonate rocks. Plants characteristic of the peatlands, such as sphagnum moss and sedge species, tolerate acidic water. The decay of dead plant material further increases the acidity of the water. Water flowing from these peatlands is quite acidic, with pH values as low as 2.4. Water movement is slow in these poorly drained areas, but when the water reaches true carbonate substrate, it seldom flows more than a few yards before diving below ground, down vertical shafts, or into cave entrances. Here, the highly acidic water from the peatlands accelerates development of karst and caves. The buffering capacity of the pure carbonates is evident, for water flowing from cave systems charged by acidic water commonly shows a pH of 7.5-8.0.

Ample precipitation drives the karst process faster

Rainfall is heavy in areas dominated by karst terrain; average annual precipitation ranges from 80 to 250 inches. Flooding occurs as well, particularly when rainstorms fall on wet snow-pack. Most of the caves studied in Southeast Alaska are hydrologically active and very dynamic. Limited dye tracing work on Prince of Wales Island demonstrated that karst groundwater systems routinely transport water thousands of feet to springs and surface streams.

It is important to understand the differences in material transport mechanisms between karst and non-karst landforms. A particle of soil in a deposit atop non-carbonate substrate must be transported by gravity, landslides and/or surface water flows, sometimes over great distances, into a surface watercourse to become sediment. Atop a karst landform, depending on the openness of the karst system, a soil particle is transported laterally a few inches or feet before it washes vertically through a solution-widened fissure of the epikarst into the deep conduits of the system. Fissures in the epikarst become injection points for water and sediments to move rapidly downward into the complex subsurface drainage system. Even the presence of a single sinkhole, which intermittently retains water, indicates the a direct surface/subsurface connection. Sediment transported from roads and disturbed lands may emerge unexpectedly at distant springs, or even across the boundaries of surface watersheds or topographies.

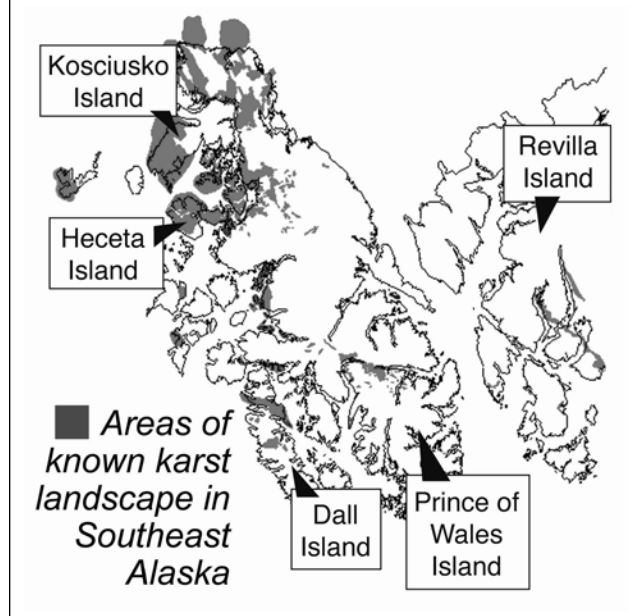
PHYSICAL GEOGRAPHY

Southeast Alaska is a narrow strip of mainland coast and hundreds of islands in the Alexander Archipelago. The islands of the archipelago vary greatly in size, from small, unnamed islands to Prince of Wales Island, the third-largest island in America. The mainland strip averages only 25 miles wide from the tidewater to the mountain crests which mark the United States-Canada border. Large peaks dominate this boundary. For example, Mt. St. Elias, in northern southeast Alaska, is more than 18,000 feet tall. The peaks on the islands are less formidable, but still range in height from 2,000 to 4,000 feet. Only small areas of karst lands have been identified on the mainland portion of the region. The majority of the karst landscapes is in the archipelago, primarily on Prince of Wales Island and on nearby Dall and Heceta islands.

Southeast Alaska consists of temperate rain forest ecosystems—a rich biological setting. As the name implies, this rain forest is the product of mild temperatures and abundant rain. The warm Alaska current, an offshoot of the northern Pacific Ocean's Kuroshio Drift, moderates temperatures: freezing winter weather and hot summer weather are infrequent and brief. Average Fahrenheit temperatures range from the high teens to the low 40s in the winter, and from the 40s to the mid-60s in the summer. The moderating influence of the ocean is even more pronounced along the outer coasts than farther inland. The maritime air masses carry great amounts of precipitation. As incoming clouds from the Pacific Ocean are intercepted by mountains of the islands and the mainland, the terrain is bathed with frequent showers and storms. Average rainfall ranges from 80 to 160 inches, although local topography and climatic conditions cause much variation. One area may receive only 27 inches a year, while another area is drenched with 400 inches.

This magnitude of moisture is pivotal in the biotic environment, just as it shapes the physical features of the karst areas. The landscape of Southeast Alaska forms an intricate

Areas of karst development in Southeast Alaska





The watery web

Southeast Alaska is an intricate network of water, terrain and life. Alpine, forest and wetland areas are interconnected by a web of streams, ponds and lakes, all of them influenced by the rainforest's moisture.



pattern of mountain, alpine, forest, and wetland terrain, all interconnected by a network of streams, ponds, and lakes. The variability of bedrock, soil and microclimatic conditions provides the foundation for a rich mosaic of ecosystems across the landscape of Southeast Alaska. The ecosystems of most relevance to the karst landscapes are those of the alpine, forest and peatland.

Alpine areas do not support tree growth above about 2,500 feet, due to their elevation, cooler temperatures and greater snow accumulation. At these higher elevations, alpine meadows and alpine tundras persist.

At lower elevations, where sites are not too wet, coniferous forests become established; they are dominated by western hemlock and Sitka spruce. Where wind-throw topples small areas of trees, sunlight reaches the forest floor and fosters growth of shrubs and herbs. Because of the great amount of precipitation, disturbance by fire is not an ecological factor.

The landscape of lower-elevation karst areas in Southeast Alaska contains nutrient-rich, well-drained soils that promote vigorous plant growth. Although the soil is shallow, well-developed subsurface

drainage encourages growth of large trees because the numerous bedrock fractures provide root-holds. The trees are anchored to better withstand strong winds. In turn, the mature hemlock and spruce forest of the karst landscape supports highly productive terrestrial and aquatic animal communities.

In areas with poor drainage, wetlands or peatlands occur. Peatlands are in fact ancient wetlands. They are dominated by mosses in the genus *Sphagnum* and various sedge species, which thrive in the acidic waters.

CAVE BIOLOGY

The terrestrial and aquatic environments of Southeast Alaska provide a variety of habitats, and the array of organisms living here is just as diverse. Caves of the region provide unique habitats and niches for many life forms. These animals, plants, and other organisms range from opportunistic users of caves to species which are totally dependent on the caves' specialized environment.

DISJUNCT and *RELICTUAL* populations of cave organisms also can provide valuable clues about ecosystems in the geologic past. Relictual cave populations can no longer live in the surface world due to long-term climatic changes, but can persist in the more stable conditions of caves. These populations are often found as isolated groups, living in caves separated by hundreds or thousands of miles.

Go into a cave and you progress through a series of environments, from a realm of light at the entrance, to the twilight zone of more limited light, and then to the region of complete darkness in the interior spaces of the cave. These environmental gradations are home for different communities of organisms. Because many of the life forms that inhabit caves are small or microscopic, we can also visualize the cave community as an interconnected assemblage of *HABITATS* and organisms, varying in size from the *MICROSCOPIC* to the *MACROSCOPIC*. All the habitats of Southeast caves also contain some degree of moisture, from slick rock to pools of water and rushing streams.

Biologists who study cave life — their work is called *BIO-SPELEOLOGY* — classify cave-associated organisms according to their degree of dependence on and adaptation to cave conditions. Three categories are used: *TROGLOXENES*, *TROGLOPHILES*, and *TROGLOBITES*.

Each of the five kingdoms of life has many representatives in Southeast Alaska caves, including some rare and unusual creatures.



Portal to a unique environment and community of creatures — where the forest gives way to the darkness of the cave, scientists and cavers find fascinating adaptations.

Creatures of the caves fit into three main categories

Trogloxenes — cave visitors: they use cave habitat for specific purposes, on a sporadic basis, and cannot complete their entire life cycles in caves.

Troglophiles — cave lovers: they have a strong affinity for the dark, moist and cool conditions of cave interiors, and sometimes show changes in their anatomy, physiology or behavior.

Troglobites — Cave dwellers: they spend their entire life cycles in the dark zones of caves and exhibit a variety of adaptations to interior cave conditions.

Bacteria, members of the kingdom *Monera*, are common inhabitants in a range of cave environments and play an important role as decomposers of organic matter. These organisms are *PROKARYOTIC* (without a nucleus in the cell). *CYANOBACTERIA*, the photosynthetic *MONERANS*, live in moist or watered sites exposed to light.

Phytoplankton, the unicellular algae of the kingdom *Protista*, are also found in the waters at or near cave entrances. Protozoans, the animal-like *PROTISTS*, inhabit the aquatic communities of all the cave zones. The bacteria and plankton are microscopic, but their sheer numbers have ramifications on the life cycles of larger organisms and on the cave environment.

Members of the kingdom *FUNGI*, which are eukaryotic and multicellular, exist in both the light and dark regions of caves. Because fungi usually obtain nutrients through extracellular digestion of dead organic matter, they act as decomposers in the food webs, like the bacteria.

Plants, of the kingdom *PLANTAE*, are photosynthetic, multicellular eukaryotes. They, of course, need light to carry out their autotrophic processes. Thus, they are restricted to cave entrances and to the twilight zone. However, the dead plant material that washes into caves is an important nutrient source for cave species.

Members of the kingdom *ANIMALIA*, multicellular eukaryotes which ingest their nutrients, belong to either of two broad categories: invertebrates or vertebrates. Most cave invertebrates are *ARTHROPODS*, with jointed legs and exoskeletons — external coverings composed of hard *CHITIN*. The other invertebrates are species of *GASTROPODS* (snails and slugs) and various kinds of worms (flat, round, or segmented). Cave-associated vertebrates (animals with internal skeletons of bone) include most of the living classes of vertebrates — bony fish, amphibians, birds, and mammals. Southeast Alaskan karstlands lie too far north to support warmth-loving reptiles.

Into the cave: a spectrum of critters

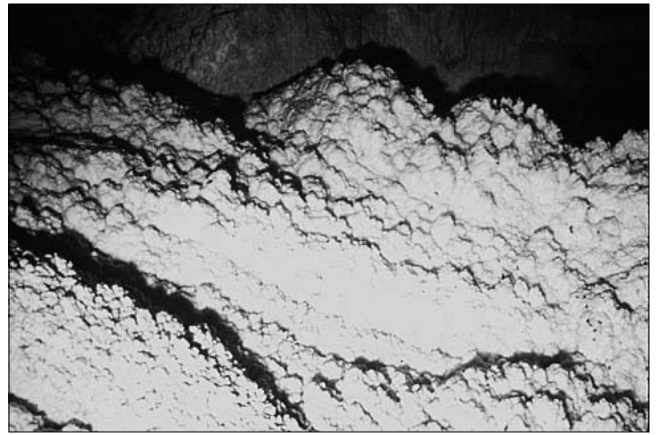
Now let's explore the organisms of southeast Alaskan caves as one moves from the cave entrance to the interior. The environment at the entrance to a cave and in the twilight zone is exposed to sunlight and is readily accessible to cave visitors — the troglloxenes. Plants, especially those adapted to

low levels of light intensity such as bryophytes (mosses, liverworts, and hornworts) and ferns, thrive at these sites. Various fungi also prosper here. Little is known about the *BOTANY* and *MYCOLOGY* of cave entrance flora, but it is probable that *RELICTUAL POPULATIONS* persist here. They have been found in other areas, such as California ferns and Illinois limestone glades.

Sitka black-tailed deer are known to rest around cave entrances both in summer, when the air coming from the caves is cooler, and in winter, when the cave entrance environment is warmer than elsewhere. Certain passerine birds — such as the dipper, at least two swallow species and three species of thrush — use entrances for nesting and foraging. Some *LITORAL* cave entrances support rookeries of cormorants, pigeon guillemots, murres, and puffins. Streams associated with cave systems support vigorous and plentiful species of fish because of their diverse and abundant aquatic invertebrate populations. For example, measurements indicate that fish from these streams grow six to eight times faster than fish from other streams. Although not yet observed, it is likely that other vertebrates such as rodent species and the region's two amphibian species, the rough-skinned newt and the western toad, utilize the resources of the entry areas. In temperate areas, amphibians are commonly found in caves, where they can shelter from dessication and the temperature extremes of the surface.

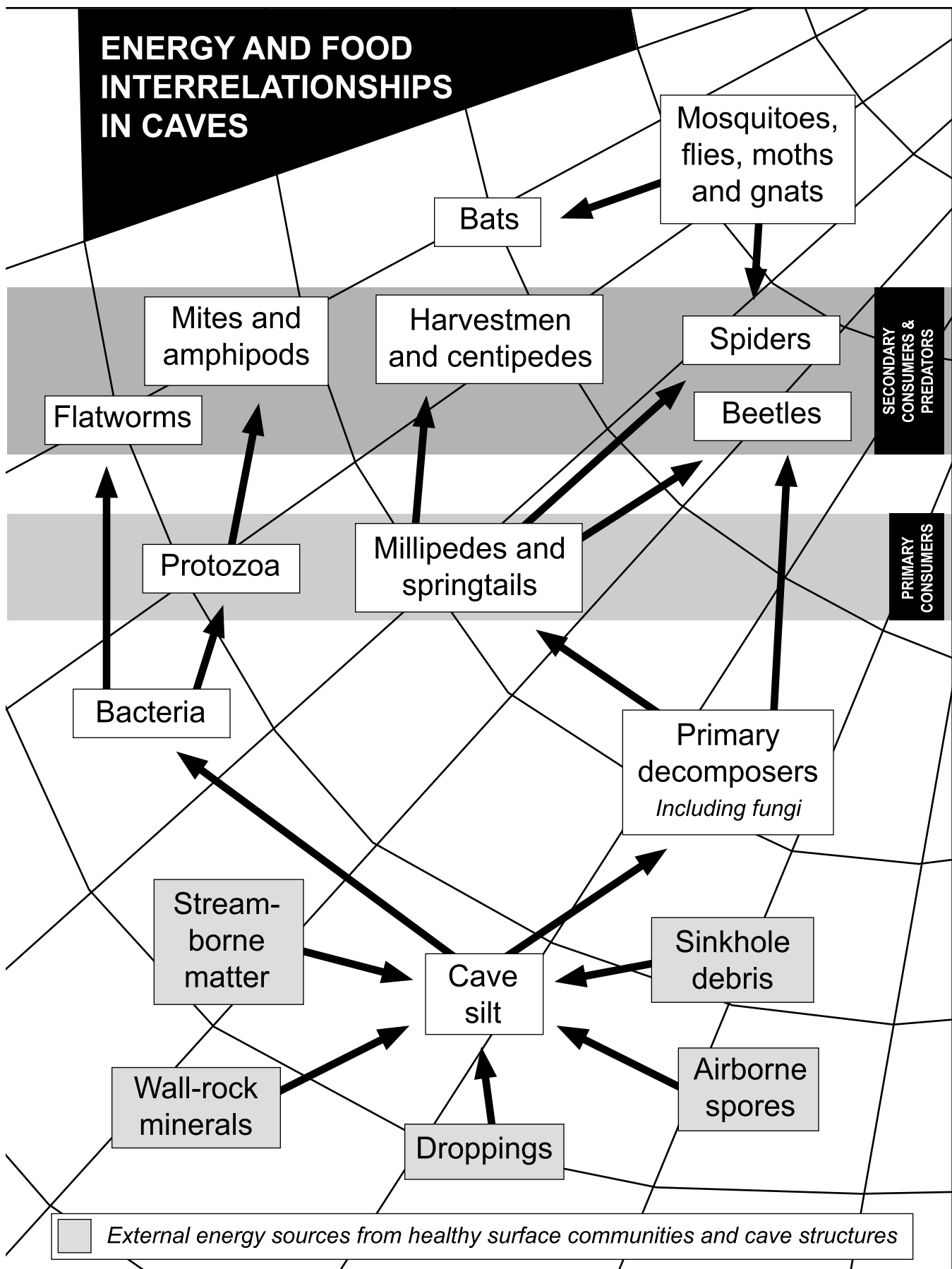
In addition to the aquatic invertebrates found in cave water, *TERRESTRIAL* invertebrate populations are present on the ground and in the soil. The moist litter of decaying organic matter and shelters such the undersides of rocks provide habitats for a diverse microcommunity of worms, snails, slugs, spiders, harvestmen (“daddy longlegs”), millipedes, centipedes, mites and beetles. Like their aquatic relatives, these troglonecrotic invertebrate populations of the terrestrial world are important components of the food webs of the cave entrance area.

Bats are probably the best-known of the troglonecrotic. Preliminary surveys in Southeast Alaska show that bats are using some of the inventoried caves. Bats pick caves that fulfill some very particular requirements: the right cave



Moon milk in a Southeast Alaskan cave — a peculiar deposit of calcite that looks a little like cottage cheese. Scientists have discovered that bacteria are involved in the unusually thick growth of this cave feature. Southeast Alaska caves contain unique microbial organisms that form these rare structures.

ENERGY AND FOOD INTERRELATIONSHIPS IN CAVES



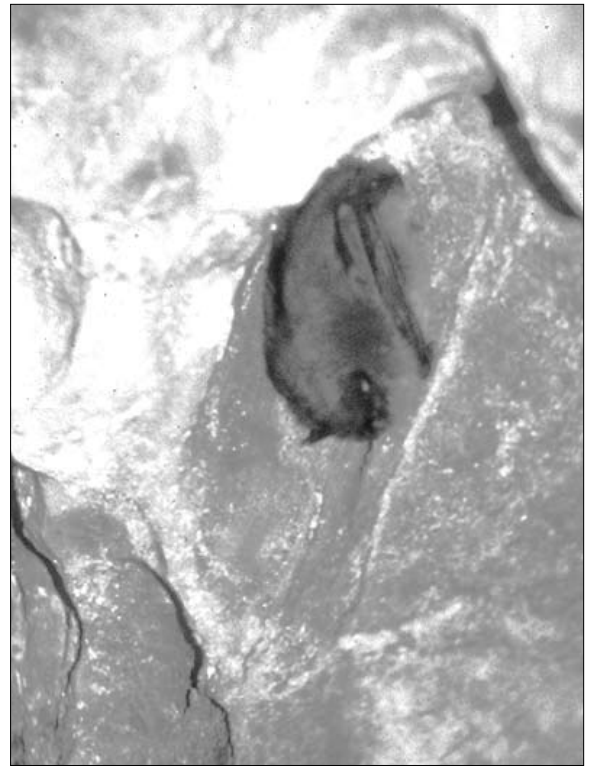
structure, appropriate temperatures and humidity, and proximity to feeding areas. Bats in Southeast Alaska eat a variety of insects and arachnids. The interaction of bats and their prey species is a vital part of the forest ecosystem. Two species of bats have been observed in Southeast Alaskan caves: the little brown bat (*Myotis lucifugus*) and the California bat (*Myotis californicus*). Another member of the genus *Myotis* has been collected in karst areas: the Keen's long-eared bat (*Myotis keenii*). The silver-haired bat (*Lasionycteris noctivagans*) may also use karst regions in Southeast.

Bats take shelter in the zone of darkness

As the twilight zone merges into the zone of darkness, some troglloxenic species also use these dark regions for more extended periods of time. Southeast Alaska caves are especially important hibernacula for bats because freezing temperatures sometimes occur outside the caves during the winter. Colonies of hibernating bats are found in the protected interior areas, where temperatures remain above freezing. It's likely that female bats also aggregate in Southeast caves to rear their young during summer months. Such maternity colonies are common in caves of locales farther south. It has been noted that other mammals, such as bears, wolves, and river otters, use interior areas for hibernating and for giving birth to their young.

The zone of darkness in Southeast caves is home to both troglophilic and troglobitic species. One study at two karst areas found more than 17 troglophilic species of terrestrial and aquatic invertebrates. On the floors of the caves, spring-tails — wingless insects with specialized springing organs — hop about while spiders, harvestmen and stoneflies cling to the walls. The calm surface of streams and pools provides habitat for white mites that skim the surface, searching for prey. Beneath the surface, flatworms, segmented worms and insect larvae move slowly on the bottom and amphipods swim through the water, filtering it for minute particles of food.

Amphipods are the best invertebrate representatives for troglophilic and troglobitic types in Southeast caves. These



A troglloxene sleeps: this creature represents one of four species of bats found in Southeast.

Troglobites: they caved in to their new environment

Troglobites are totally dependent on the cave environment. Their adaptations are well-developed: small bodies and long limbs; receptors that are highly sensitive to chemical and tactile stimulation; reduced or lost vision; lowered metabolic rate; and greater efficiency in movement and feeding behaviors.



This spider tracing its way across moon milk is a troglophile: it often visits the cave for shelter or food, but it's just as much at home in moist, dark places outside the cave.



FOR BEST ADAPTATION BY A SPECIES FROM ANOTHER ENVIRONMENT, THE NOMINEES ARE ... This amphipod typifies the cave-adapted features of the troglobite: a small body, long appendages and sightlessness. This *Stygobromus* was discovered on Heceta Island. It's virtually identical to its counterparts in caves on Vancouver Island. Our area of Southeast Alaska is the farthest-north extent of *Stygobromus*.

animals are members of the crustacean subphylum, which also includes shrimp, lobsters and crabs. Their laterally compressed bodies give amphipods a shrimplike appearance. The occurrence of the troglophilic amphipod *Cratigonyx olliquus richmondensis* is the first observation of this species in any cave in northwestern North America. Troglobitic species of amphipods, such as the blind *Stygobromus quatsinensis*, have been collected from cave groundwater on Dall and Heceta islands of outer Southeast, but not from cave systems on Prince of Wales Island. This may indicate that glaciation caused the extinction of cave-adapted species on Prince of Wales Island, but that the outer islands were ice-free and thus retained the troglobites.

Troglobites are distinguished from troglophiles by their total dependence on the cave environment, and by a range of adaptations to this environment. These adaptations include small bodies and long limbs, highly sensitive receptors to chemical and tactile stimulation, reduced or lost vision, lowered metabolic rate, and greater efficiency in movement and feeding behaviors. The last two types of adaptations especially reflect the limited amount of nutrients available in the dark cave interiors. Without the rich source of food from photosynthetic organisms, food chains and webs in the dark zone involve more limited nutrient sources, with bacteria, fungi, and invertebrates playing the important roles. All these organisms are ultimately dependent on the flow of water from the surface world, which carries inorganic and organic nutrients to the obligate cave dwellers.

An intriguing potential bacterial association may occur in moonmilk, a deposit of calcium carbonate which reaches a thickness of several feet in some southeast Alaska caves. Bacterial species may be involved in the unusually thick growth of these formations. Clearly, caves of Southeast Alaska hold mysteries of life yet to be discovered.

PALEONTOLOGY AND ARCHAEOLOGY

Over the last decade, a small group of people has emerged with a determination to bring light to the mysteries of the limestone caves of the Alexander Archipelago. They come from diverse ethnic and professional backgrounds and include archaeologists, paleontologists, biologists, geologists, hydrologists, divers, pilots, fishermen and loggers. By pooling their information, they are piecing together the cultural and ecological past of Tongass National Forest.

The caves are on beautiful rain-drenched islands separated from the mainland of Alaska and British Columbia by wide straits. Strong currents, extreme tides and unpredictable weather dominate. The islands' rugged mountains rise sharply from the shore. The land is densely covered with trees, shrubs, bushes, ferns and mosses. The caves on these islands have preserved animal bones, tools, wood, and artwork. Cool air, constant temperature and high pH levels protect artifacts from decay. These keys to the past are sheltered from weather, wind and animals that might move them.

Archaeology is a wet business

Outside the caves, the weather and the rain-forest environment of Southeast Alaska make it difficult to find archaeological sites. Plants, bushes and huge trees grow quickly, covering sites and artifacts. The Sitka spruce, red cedar and hemlock trees of southern Southeast Alaska grow into giants and when they fall they bury sites under massive amounts of organic material. The most detrimental factor for the preservation of archaeology though, is the destructive ability of the highly acidic water flowing out of the muskegs or wetlands, over organic artifacts. The extremely low pH of the water quickly breaks down and destroys organic artifacts. This means wooden spears, bone points, carved wooden implements, woven mats and baskets, sinew threads, and many,

Illuminating the darkness— diverse explorers go into the Southeast Alaskan caves



A member of a scientific exploration team drops carefully into a Southeast Alaskan cave. Sophisticated equipment, good preparation and teamwork are prerequisites for this work. The results are significant for biologists, paleontologists, archaeologists, geologists and others with an interest in the region's underground world.



This fossil bear skull and the remains of other animals taken from the caves tell scientists a lot about ancient climates and seacoasts. They can also provide clues to the human history of this region.

many other aspects of domestic life are all quickly lost to the elements. Only the inorganic materials survive, usually in the form of stone tools, commonly referred to as lithics. However, the limestone in the caves has a very high pH which neutralizes the naturally acid waters of Southeast Alaska and allows for excellent preservation of these and other organic artifacts.

Discoveries of many caves accompanied the intensification of logging and other development on the Tongass National Forest. Scientists working for the USDA Forest Service studied the caves and found entire karst systems. Their job was to inventory resources to determine whether proposed uses were

appropriate. The Forest Service was concerned about preserving water systems, animal habitat, and archaeological sites while permitting responsible development and timber harvest. As scientists and loggers found more and more caves, they recognized that important new information was being discovered.

Forest Service scientists shared their discoveries with other scientists around the world. Now, many cave experts travel to the islands of Southeast Alaska each summer to search for evidence about how the island environment has changed since the last ice age. They also look for clues about how ancient peoples traveled throughout the islands and how the caves served for shelter and ceremonies.

Although the Pleistocene and Holocene vertebrate record has captured the attention of researchers studying the evolution of the modern environment, a far older history is captured in the caves. The Devonian and Silurian limestones that form the medium for cave formation contain a fascinating invertebrate fossil record of a period 450-350 million years ago. Nautilus Cave on Heceta Island was carved from Silurian gray and black marbled limestone. Spaces between the stromatolites hold gastropod and brachiopod fossils that are replaced by white calcite or stained red by iron oxides.

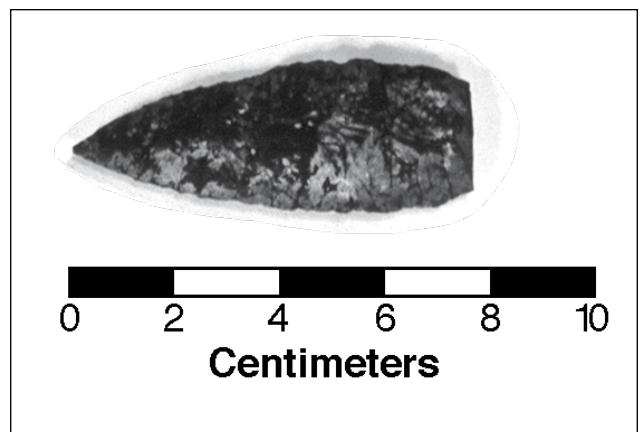
The caves of Southeast Alaska are a paleontologist's dream. Bones of animals trapped over thousands of years rest in countless sinkholes across the landscape. There is an undisturbed record of the animals that inhabited the area. Scien-

tists are doing paleontological work where the caves' stable environment has preserved shells, bone, teeth, feathers, fibers, wood and charcoal. A single marmot tooth dated to more than 44,500 years ago was found in a cave on the west coast of Prince of Wales Island.

Bones from black bears (*Ursus americanus*) in an important cave on northern Prince of Wales Island have been dated to 41,600 years ago. Bones of brown or grizzly bears (*Ursus arctos*) from this cave have been dated to 35,363 years ago. To date, the remains of 16 brown bears have been recovered from caves in the southern Alexander Archipelago; they range in age from 35,363 to 7,205 years ago.

The blackened humerus of a deer or caribou was radiocarbon dated to 8,300 years ago. Other remains in the caves include a ringed seal dated to 17,600 years ago and a caribou dated to about 10,600 years ago. These mammal finds, combined with the presence of tundra voles and red foxes found in deposits, suggest that a landscape similar to that near present-day Kotzebue, Alaska, might have existed long ago in Southeast.

A hibernaculum was discovered in El Capitan Cave on the west coast of Prince of Wales Island, in a glacial valley some 400 feet above present sea level. It contained the remains of at least four black bears and three grizzly bears, ranging in age from 12,300 years ago to 6,400 years ago. The bones of these bears were stained a dark, mahogany red and some were extremely well-preserved. Also recovered were the bones of bats, river otters and a red fox; the skull and jaw of an ermine; and many small fractured fish. Fish bones dated to 5,770 years were discovered. They had passed through the digestive tracts of river otters. Under two large rocks in the alcove, test digging revealed the skull and bones of a juvenile river otter sandwiched between fragmented cedar bark or matting. The otter was dated to 3,290 years ago. The cave may have been used as a natal den 6,000 years ago and perhaps visited by humans using cedar bark mats about 3,300 years ago. Grizzlies and marmots are extinct now on Prince of Wales Island.



Cultural artifacts such as this projectile point fashioned from dark grey chert, dated about 9,800 years ago, may be clues to human migration and habitation along this part of the coast. Scientists are watchful for circumstantial evidence for a theory that people with boats and navigation skills migrated southeastward along the Gulf of Alaska coast tens of thousands of years ago.

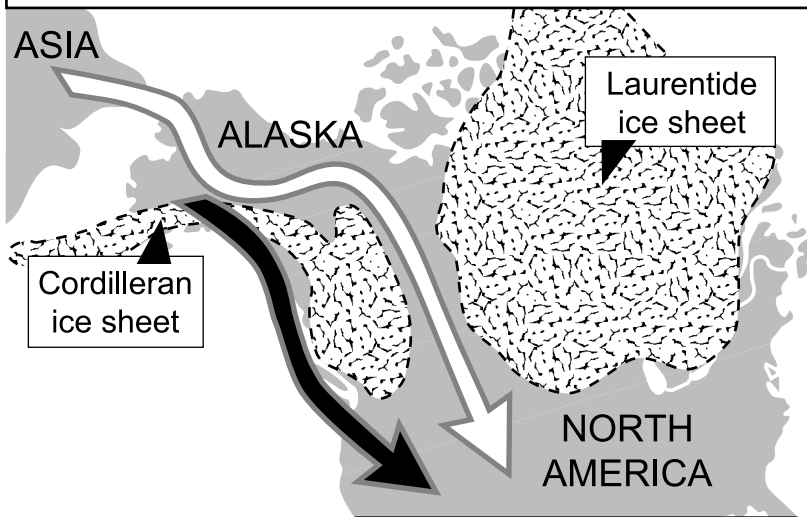
Grizzly bears and black bears do not coexist on many of the islands of Southeast Alaska, but they do share the ground on the coastal mainland. It's possible that, before the end of the ice age and the rise in sea level, the outer coast of Southeast Alaskan islands was physically similar to present coastal mainland. As the sea rose, the two species were isolated together on islands. Black and grizzly bears did overlap at El Capitan Cave from 11,565 to approximately 7,000 years ago. The hibernaculum was open between 12,300 to 6,400 years ago. Grizzly bear fossils were also found in Blowing In the Wind Cave. These were dated to 9,995 years ago

and provide more evidence of an early grizzly bear population on Prince of Wales Island. Scientists previously believed that ice covered Southeast Alaska until 10,000 years ago. These bears could not live in a glaciated environment because of inadequate food and shelter. Therefore, the presence of a 12,300-year-old grizzly bear in El Capitan Cave pushes the ice-free date back about 2,300 years. Significantly, both bears and humans are omnivores. It is very likely that where bears could live, humans could also live.

For many years, most archaeologists believed that human migration to North America from Asia was blocked by massive glaciers in Alaska and Canada during the Pleistocene ice age. But recent

evidence from karst regions in Southeast Alaska indicates that the southwesternmost islands of the Alexander Archipelago may not have been glaciated in the late Pleistocene. This region may have been a corridor for human populations much earlier than scientists thought possible. We see two indicators of an early coastal refugium: remnants of Pleistocene plant communities in alpine areas and greater genetic variation in chum salmon populations. Surveys by the Tongass Cave Project reveal caves and passages that predate the end of the Pleistocene. They would have been crushed by the ice had they been glaciated at the end of the

PLEISTOCENE PATHS: theorized routes of ice-age migration from Asia to North America



Conventional theory: hunters of large mammals followed herds from Asia via an ice-free corridor east of the Rockies.

Flandmark theory: humans with boats migrated south along the coast 40,000-11,000 years ago, avoiding ice obstacles.

Pleistocene. Not only do the caves exist, but paleontological and archaeological components in them indicate they were ice-free.

Who was here first, and how?

Speculations about the first inhabitants of the Northwest Coast and the first human entry into North America are among the most intriguing topics of current archaeological research. In the “traditional view” popular for most of the 20th century, early Asian migrants traversed the Bering Land Bridge and followed herds of megafauna, or large prey animals, such as caribou and bison south through an ice-free corridor between the Cordilleran and Laurentide Ice Sheets, eventually entering into the northern plains and dispersing across North and South America. Another theory, introduced by Knut Fladmark in 1975, is gaining acceptance among archaeologists studying the Northwest Coast. According to this theory, as recently as 11,000 years ago or as early as 40,000 years ago, people with boats and ocean-going navigation skills migrated south along the coast. These people followed the exposed southern shore of the Bering Land Bridge, along the Alaska Peninsula and Gulf of Alaska, eventually traversing the exposed continental shelf of the Alexander Archipelago on their way south.

Evidence for this theory is sparse and circumstantial at present. Study of the glacial history and paleontology of the coastal route suggests that no insurmountable obstacles to the journey existed and that ice-free refugia existed between 10,000 and 12,000 years ago and possibly even as much as 38,000 years ago on Prince of Wales Island. An obsidian source on Suemez Island was utilized for tool manufacture as early as 9,500 years ago. This distinctive volcanic glass has been found at archaeological sites in northern southeast Alaska and in British Columbia. This provides evidence that a boating people with an intimate knowledge of the resources was present in southeast Alaska at that time. Such familiarity suggests some length of occupation.

In 1996 a remarkable find was made by Dr. Timothy Heaton, a paleontologist working in a cave on north Prince of



A link to the past: *this drawing reminds us that caves have provided shelter and a cultural canvas for Native inhabitants for millennia.*



Some caves in Southeast Alaska result from physical weathering. Littoral or sea caves found along the coast demonstrate this process, as at this Baker Island site.

Wales Island. Portions of a human skeleton and three tools were recovered from the same cave that had previously yielded bear bones dating to 41,600 and 35,363 years ago. The human bones proved to be about 9,800 years old, the oldest from Alaska and the Northwest coast, and offered a tremendous opportunity to learn about the early peoples in this area.

Human presence in Southeast Alaska

All of this supports the theory that there was a human presence in Southeast Alaska significantly earlier than 10,000 years ago. We still have not found that elusive site of 15,000 or more years ago where the first migrating groups of humans sat out bad weather and wondered what was ahead to the south. The search for such sites intrigues archaeologists and geologists of the Outer Island Cave Inventory Project, as well as many of the speleo-specialists of the Prince of Wales Island Expedition. The search brings together diverse scientific disciplines to answer questions such as: Where was the shoreline 15,000, 13,000 or 11,000 years ago? What species of marine and terrestrial animals were present? When were anadromous fish runs established and where?

What plant resources were available and how were they distributed? In short, what *PALEOECOLOGICAL* clues are present to help us narrow down the search for the first human inhabitants of Southeast Alaska?

Understanding the changes in sea level with the melting of the Pleistocene glaciers is a major factor in finding the older sites. The sea level 17,000 years ago was 120 meters lower than it is today. The ice melted and by 10,000 years ago sea level was a few meters to as much as 100 meters higher than today—depending on the local magnitude of isostatic rebound, in which the earth rises as its burden of glacial ice is removed. For most of the time prior to 10,000 years ago, the shoreline was much lower than it is today. The archaeological remains of coastal camps from those times are now under water and difficult to find. Therefore, the search has focused on inland or elevated locales, where hunters and foragers would have sought temporary refuge. Caves offer the best opportunity for finding such sites.

Cave archaeology also sheds light on the more recent past

The bulk of archaeological evidence from caves in southern southeast Alaska is less than 4,000 years old. Most significant deposits are from rock shelters and shoreside caves rather than from deep solution passages. Only at El Capitan Cave do we find artifacts 600 feet back in a solution cave.

Researchers are trying to determine the role of caves in the settlement pattern and seasonal round of inhabitants of Prince of Wales over the past several thousand years. Shells, animal bones, charcoal and a few broken tools provide the best evidence of what people were doing in caves. There are also a few caves with beautiful rock art panels. Archaeologists made exciting discoveries in one cave: two decorated wooden planks and an L-shaped wooden club. The planks have unique carved and painted designs and seem to have been made for connecting with lashing: in fact, cedar cordage was found in holes in the planks. Broken fish spines are embedded in the club and archaeologists think it may have been used as a fishing tool.



This wooden artifact is believed to be a fish club — used and left behind 4,500 years ago by people who took shelter in a cave.

Memories and oral histories of the Tlingit, Haida, and Tsimshian peoples are important sources of information on these caves and their uses. Alaska Native peoples of Southeast Alaska have a rich heritage and deep knowledge and understanding of the area and its resources. Their histories recount the spiritual as well as the everyday significance of localities in Southeast Alaska.

SAFETY IN THE CAVES

Caves throughout the world are fragile places of mystery, wonder and beauty. But they are also places of danger.

Caves in Southeast Alaska can pose greater danger than others when cavers enter them without proper preparation.

The National Speleological Society's observation is especially valid for Southeast Alaskan caves: "Reasonable safety in caving can be achieved only through a combination of a proper attitude, good equipment and training from those already well-versed in the specialized techniques of cave exploration."

Caves are dark, so take several sources of light. The type and quantity of lights used in Southeast Alaskan caves are important considerations. These caves typically are wet and cold and contain rugged passages; they are in remote areas. Although a flashlight provides bright light, it is difficult to maneuver in the passages while positioning the flashlight.

Climbing through windy passages while carrying a flashlight is a challenge best avoided. The best solution is to use headlamps. It is also important to carry at least three reliable sources of light per person.

Extra lights are vital if first sources fail, if a partner's source goes out, or if lights are lost or broken — all common occurrences. Be sure to start with new batteries and test every light before entering the cave.

A hard hat is the second most important item of equipment. No matter what care the caver takes when negotiating difficult moves, encounters with the hard rock interior can happen. It is especially important to protect the head. Limestone can also

be very sharp and the hard hat protects the head from cuts as well as impact injuries. It's useful for the hard hat to be secured by a quick-release device; even if the hard hat is jammed in a crevice, the caver's head can be freed. A light mounted to the hard hat frees the hands for maneuvering, but it adds weight.

To explore Southeast Alaskan caves, dress as if preparing to hike in the forest during the winter. Caves drip water throughout the year, so it is a good idea to wear some kind of tough, water-resistant cloth as outer protection. Under-



A caver prepares his equipment. Most Southeast caves are at least partly vertical; proper gear is essential for safe exploration. Technical training is also a good bet for safety.

neath exterior clothing, wear several layers of warm clothes so that some can be removed during strenuous activity, or replaced during less-active periods. Wear or bring plenty of clothes. Caves are about 40 degrees Fahrenheit year-round, so hypothermia is a threat. Sturdy boots with slip-resistant soles are important. A small pack is useful for carrying extra clothing and equipment.

File a trip plan before going into the caves

Before departing for a cave, be sure to arrange for a “surface watch”: a person who knows exactly where you are going, and when you plan to be out of the cave, and who has contact information that can aid cave rescue personnel in an emergency. When you leave the cave and return home, immediately get in touch with your surface watch to let them know you are safe. Even cavers on professional expeditions file daily trip plans. In the harsh underworld environment, little incidents can lead to major difficulties. Someone will be alerted to take action if accidents or complications knock you off schedule. It’s also a good practice to notify friends or family about your itinerary: destination, expected time of return, etc.

Before deciding which caves to explore, find out which caves are subject to flooding. Some caves in Southeast Alaska can flood two days after rain stops. Consider the length of time to be spent in the cave and recent and current weather conditions outside the cave. If there is any concern about flooding, do not enter that cave. You can wait for a future trip.

While hiking to the cave, remember that although more than 500 caves have been identified, hundreds more wait to be discovered. Watch for cave entrances that might be covered with vegetation. Since many cave entries in Southeast Alaska are vertical shafts and pits, careful observation of the terrain is also a safety precaution.

After entering the cave, move slowly and take note of all the surroundings. Careful exploration prevents the accidental breaking of delicate formations. Watch for side passages and have some way of marking the main passage. Use some method that will not disturb the cave. If survey tape is used, be sure to pick it up on the way out. Know your limits and never exceed them. Unlike a mountain hike, the trip out of the cave can be just as strenuous as the trip in, so save

Good gear makes for safer cave exploration

- Use headlamps
- Carry at least three reliable sources of light per person
- It is especially important to protect the head: wear a hard hat
- Wear some kind of tough, water-resistant cloth as outer protection

Consult an expert for information on caves

Information and training for exploration of Southeast Alaskan caves is available through the Glacier Grotto in Ketchikan. For information on caves and caving nationwide, get in touch with the National Speleological Society at Cave Avenue, Huntsville, AL 35810; telephone 205-852-1300.

enough energy for the return trip. Remember that it can be easy to climb up something that is very difficult to climb down. Turn around often and look back. Many people get lost on the way out because the cave looks very different from that perspective. Look up at the ceiling for rocks that might fall.

Careful observation increases the safety and enjoyment of the trip. Cave decorations can be quite dainty but very beautiful. Bats can be small enough to fit into a 35mm film canister. Other organisms are even smaller. Fossils and bones can blend into surrounding rocks. It takes a keen eye to see these things.

The Rule of Three makes for smart caving

It's always a good idea to team up in a cave and experts recommend at least three people in the party. If one member of the team is injured, another person stays to care for the injured person while the third goes for help. One member of the party should bring first aid supplies and a small quantity of survival gear; a space blanket is a good item to have. If the trip is to be very long, carry food and water. Caving requires much energy simply to stay warm and it is important to maintain a high energy level. Water in the cave is subject to the same problems as on the surface, so don't drink the water in the cave without first purifying it. Partners can also watch for signs of stress in each other. Stress can include chills, discomfort in small areas, fatigue, hunger and fear of the unknown. A team that enters a cave should depart as a team, with one exception: when there is an adequate number of team members to leave some individuals behind, at least one of whom has experience in that cave, or is an experienced caver. A person who wishes to leave should not be made to feel badly. It's not a good trip unless everyone is having a good time.

Sometimes, despite all precautions, cavers get disoriented and lost. What to do? The worst thing is to rush up and down passages. That will probably lead to more disorientation. Don't panic. Stop, think, and assess the situation. Remember that it's impossible to panic if your breathing is normal. If there is immediate danger, move to a safe area and stay there. Move in place to stay warm. This common emergency emphasizes the importance of leaving a trip plan with your surface watch, along with family or friends. A detailed itinerary facilitates an informed rescue effort

Technical gear may be needed

It is important to remember that most of the caves in Southeast Alaska are vertical. Technical training and proper gear are essential if rope is needed for exploration. Mud, unstable rock, humidity and total darkness underground can't be surmounted with the usual above-ground climbing techniques.

USDA Forest Service has information on the caves of Tongass National Forest. Two cave sites have been developed by the agency for easier public access. Cavern Lake Cave has a trail and viewpoints at the entry area. Swimming through the cave should not be attempted due to the dangers of hypothermia and drowning. An excellent trail leads to El Capitan Cave and guided tours of the front passages are available during the summer. This cave is subject to rapid flooding and a gate was installed at the entrance to eliminate entrapment. El Capitan also has other hazards, such as deep vertical pits. Exploration of even developed caves in Southeast Alaska requires care and caution.

CONSERVATION IN THE CAVES

Every time people enter a cave, some kind of impact results. For example, in Carlsbad Caverns, New Mexico, species of microscopic organisms now line the visitor paths, waiting for hair, dead skin and other particles people shed as they pass through. These species were not there before humans entered. In another instance, ancient paintings in the caves of southern France are decomposing due to changes in the caves' climatic conditions caused by visitors. Visitors to developed caves and cavers in "wild" caves should minimize their impacts on cave environments.

Responsible cavers leave no signs of their presence and pack out any signs other parties may have left behind. They move slowly through caves and carefully consider their next sequence of movements. They watch the placement of muddy hands. Conservation-minded cavegoers try not to



Cave explorers find a raw beauty in formations such as this stalactite and stalagmite. And though such features develop over decades or centuries, they can be ruined in a moment. (See *El Capitan Management plan* in the appendices for more information.)

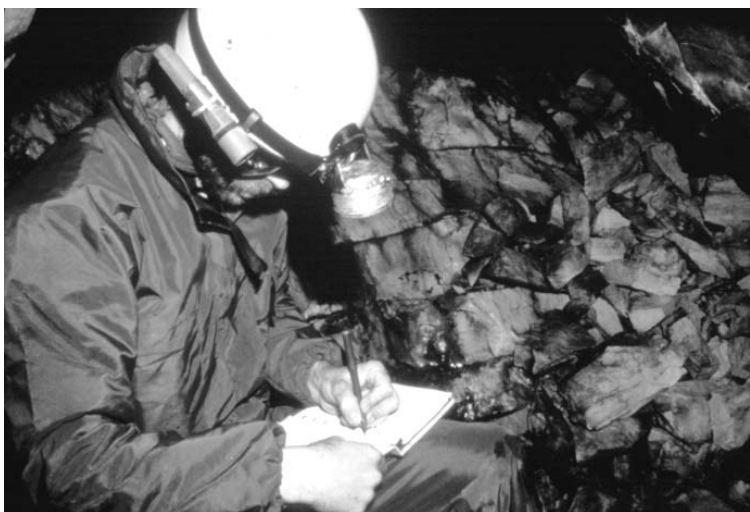
Get info on Alaska's karst landscapes

For more information on Tongass National Forest caves, contact USDA Forest Service staff ...

■ Forest Supervisor in Ketchikan
at 907-225-3101

■ Craig Ranger District Office
at 907-826-3271

■ Thorne Bay Ranger District Office
at 907-828-3304.



Help science, but don't hinder nature. *If you find an apparently valuable object in a cave, don't take it out or get a sample. Just note its position. Sketch it. And then report it to cave experts.*

lose their balance and accidentally grab some decoration; contact with even skin oil can stop formation of stalactites or stalagmites. These formations grow continually, over hundreds of years, and should not be disturbed. A removed formation may be decorative in a home, but it is even more beautiful in its natural setting, where many more visitors can enjoy it. Careful cavers leave alone any broken formations they find: removing broken formations simply encourages further collection. Visitors should bear in mind that many cave passages remain unsurveyed, because entry into the passages would have damaged the formations. No-impact cavers know to avoid handling or moving something of scientific interest,

because its scientific value can be diminished. They note its position in the cave and notify a professional later.

Although it is a thrill to see a large wall of flow stone, moon milk, or a stalactite, cavers should take time to watch for cave popcorn and small fossils. Cave popcorn, a formation of delicate crystals, is very common in Southeast Alaska caves. Fossils embedded in cave walls have drawn micropaleontologists to Southeast Alaska from other areas of the country for several years. Sometimes bats may be seen in the caves. It's important not to disturb them. A hibernating bat can use up most of its stored energy if it is disturbed and will be unable to live through the winter.

The Tongass Cave Project in the late 1970s led the initial effort to increase awareness of cave resources. The value and the vulnerability of Southeast Alaska caves were recognized in the 1980s, with El Capitan (or El Cap) Cave first in focus. In 1984, USDA Forest Service staff saw the recreational potential at El Cap about the same time as they noted vandalism to formations inside. By 1992, they were developing a management plan and solutions to vandalism. Forest Service staff decided that a gate would most effectively prevent vandalism to fragile speleothems and disturbances to little brown bats — *Myotis lucifugus*. The management plan further identified the need to control access beyond a gate and looked at protecting recreational cavers from several deep pits along the main passage at El Cap Cave.

The Forest Service installed a so-called air flow bat gate about 150 feet inside El Cap Cave during the summer of 1993. A lot of research and experience went into the gate. Roy Powers of the American Cave Conservation Association and Robert Currie of the U.S. Fish and Wildlife Service were consultants on the design. Jim Nieland of the Forest Service contributed on-site design and construction. The gate was welded and installed by Robert Wetherell of Thorne Bay Ranger District. Air flow, temperature, humidity and deterring human intrusion are essential factors in a successful design. A heavy steel gate with few opening will keep people out, but won't allow proper air exchange and regulation of temperature and humidity — requirements to maintain an undisturbed population of bats and to preserve growth of cave formations. A properly used gate is one of the most powerful tools for implementing and enforcing a cave closure. Gates are, on the other hand, expensive to install and to maintain. They can also be ineffective if they're designed poorly or installed incorrectly — or if they're not part of a comprehensive management plan.

Not much is known about the effects of gates on caves. Some caves have flora and fauna that are susceptible to the minutest of changes. At a minimum, efforts should be made to study a cave before and after installation of a gate in order to record these effects. Future designs should take such effects into consideration and should be modified to accommodate them.

The bats *Myotis lucifugus* and *Myotis californicus* have been seen behind the gate at El Cap and don't seem to mind flying past the gate. The eastern species *Myotis grisecens*, or gray bat, isn't so easygoing: the bats will not tolerate any kind of full gate on their maternity caves, but will tolerate some gating on hibernation caves. This goes to prove that cave gating is an inexact science.



Tongass Cave Project volunteers were pioneers in discovering, mapping and protecting Southeast Alaska's caves, starting in the 1980s.

El Cap Cave gate: a ton of prevention

Weight of steel 2,100 pounds

Cost of steel \$2,000

Labor cost \$9,000

Logistical support cost \$4,000

Configuration horizontal steel members 5.75 inches apart keep out people, let in air, allow bats to pass in and out



Forest Service scientists and technicians such as this group pictured in the 1990s have been instrumental in both exploring and managing these unique karst areas.

The best way to protect the cave is for cavers to be on the alert for all the wonders of the cave, large and small. They can then avoid moves or actions that could damage the caves. By following these guidelines, cave visitors can ensure that the caves are protected and we can continue to enjoy the mystery and beauty that lie underground.

The karst landscapes and caves of Southeast Alaska offer a precious legacy to scientists and everyday people—including students and teachers. The fascinating geological stories they tell and their unique influences on the rain forest ecosystem are nature's textbooks for studies ranging from tectonic drift to human migration.

APPENDICES

Map of El Capitan Cave

Recommended Bibliography

Glossary

Map of Karst Areas in Southeast Alaska

Educational Activities

El Capitan Cave Management Plan

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GLOSSARY

ALKALINE Water or another substance with a pH (percentage of hydrogen) greater than 7. Acidic water (pH less than 7) from muskegs can be neutralized and become alkaline by reacting with the calcite of karst formations.

ALPINE Higher-elevation terrestrial region, above treeline, and often the associated vegetation community. Alpine epikarst typically lacks vegetation.

AMPHIPOD Small crustaceans of the group *Amphipoda*, including beach fleas and sand hoppers.

ANADROMOUS Migrating from the sea up a river to spawn, as in salmon species.

AQUATIC Of, in, or pertaining to water; living or growing in water.

AQUIFER A permeable subsurface stratum, or zone, through which groundwater moves in sufficient quantities to supply water for wells and springs.

ARCHAEOLOGY Scientific study of historic or prehistoric peoples and their cultures by analysis of their artifacts, inscriptions, monuments and other such remains, especially those that have been excavated.

ARCHAEOLOGICAL SITE A scientifically administered location that yields evidence relating to historic or prehistoric peoples and their cultures; may be above ground, in a cave, buried below ground level, or even under water.

ARACHNID An arthropod of the class *Arachnida*, comprising 57,000 species of spiders, scorpions, mites and ticks. Most are terrestrial, breathe air and have four pairs of walking legs.

ARTIFACT A human-made object, such as a prehistoric tool, weapon, or pottery shard.

ARTHROPOD Any segmented invertebrate of the phylum *Arthropoda* having jointed legs and exoskeletons composed of hard chitin; includes insects, arachnids, and crustaceans. This largest phylum in the animal kingdom, with more than 1 million species classified to date.

AUTOTROPHIC Capable of utilizing only inorganic materials as a source of food, as most plants and certain bacteria and protozoans.

BEDROCK Solid rock that lies beneath the soil. In karst landscapes the bedrock, often limestone, is soluble (can be dissolved) by the chemical action of carbonic acid and is referred to as soluble bedrock.

BERING LAND BRIDGE The connecting land mass which existed between Siberia and Alaska during the last glacial advance, which lowered sea levels. People and animals may have migrated along this continental connection 15,000 to 11,000 years ago.

BERINGIA Referring to the Bering Land Bridge region of the last ice age.

BIOSPELEOLOGY Exploration and study of the flora and fauna (plants and animals) of caves.

BIOTIC Of or pertaining to life; typically, plants and animals in a natural environment or ecosystem.

BOTANY Scientific study of plants, plant life and plant communities of a region.

BRACHIOPOD A mollusk-like marine animal, phylum *Brachiopoda*. These animals have hard dorsal and ventral shells, resemble clams and feed by means of a lophophore. They are represented by 30,000 extinct species and 250 living species.

BRECCIA Rock composed of angular fragments of older rocks cemented together.

CATCHMENT Something that catches water.

CAVERN/CAVE Any naturally occurring void, cavity, recess, or system of interconnected passages which occurs beneath the surface of the earth or within a cliff or ledge and which is large enough to permit an individual to enter, whether or not the entrance is naturally formed or human-made. This includes any natural pit, sinkhole, or other feature which is an extension of the surface. (From the Federal Cave Resource Protection Act, 1988.)

CALCAREOUS Containing calcium carbonate.

CALCITE A common mineral, also known as calcium carbonate, that occurs in a great variety of crystalline forms. It is a major constituent of limestone, marble, chalk and the exoskeletons of many marine organisms.

CAVE POPCORN A formation of delicate crystals.

CEMENTATION Binding and cohesion of sediments to form a solid mass.

CHIROPTERA The order of animals comprising the bats.

COMPACTION Consolidation of sediments resulting from the weight of overlying deposits.

CONGLOMERATE Rock containing worn and rounded stones embedded within a finer cementation.

CRUSTACEAN An arthropod of the class *Crustacea*. An aquatic creature with compound eyes, two pairs of antennae and one pair of mandibles. It is represented by lobsters, crayfish, crabs, shrimp, and the shrimp-like, but much smaller, amphipoda.

CYANOBACTERIA Photosynthetic moneran autotrophs (bacteria), known as blue-green algae, but including species of many different colors, living in moist or watered sites exposed to sunlight.

DECAY Entire or partial dissolution, deterioration, or decomposition by progressive natural processes.

DIKE A long, narrow and more or less vertical mass of igneous or eruptive rock intruded into a fissure of surrounding older rock.

DISJUNCT Disjoined or separated; as in organisms living in caves hundreds or thousands of miles from like organisms.

DISORIENTATION Confusion concerning relative location and position; loss of sense of direction.

ECOLOGY The branch of biology that studies the interactions of organisms with their physical environment and with each other, and the results of such interactions.

ECOSYSTEM A system formed by the interaction of a community of organisms with their biotic and abiotic environment.

EPIKARST A highly dissolved land surface consisting of an intricate network of intersecting roofless dissolution-widened fissures, cavities, and tubes dissolved into the carbonate bedrock. Other features include vertical fractures, shafts, spikes, spires and eroded rills of carbonate rock.

EUKARYOTIC Cells with a membrane-bound nucleus and membrane-bound organelles.

EXOSKELETON The outer supporting covering of an invertebrate body; common in arthropods.

EXTINCT No longer existing; died out.

FAULT A break in the continuity of a body of rock, attended by movement along the break.

FLORALTURBATION A disturbance process involving plants that changes the context of the archaeological record and affects interpretations of the locations and conditions of artifacts.

FLOW STONE Smooth sheets of calcite deposited by water flowing down the walls of a cave. Crystals in the deposits grow perpendicular to the flow.

FORMATIONS Either a body of rocks, or stratum, classed as a unit for geologic mapping; or a deposit of calcium carbonate material of various types, shapes and sizes, such as stalactites, or stalagmites.

FUNGI Plants without leaves, flowers, or chlorophyll which usually obtain nutrients through extracellular digestion of dead organic matter. Eukaryotic and multicellular, they act as decomposers in food webs, like bacteria. Examples are mushrooms and molds.

GASTROPOD Asymmetrical mollusks of the class *Gastropoda*. These invertebrates with spiral shells and heads with one or two pairs of tentacles, include snails, whelks and slugs.

GEOLOGY The science that deals with the physical history of the earth, the rocks of which it is composed and the physical changes which the earth has undergone or is undergoing. Also refers to the geologic features and processes occurring in a given region of the earth.

GLACIER An extended mass of ice originating from a region of perpetual snow, either moving slowly downward from high elevations as mountain-valley glaciers or moving outward from centers of accumulation, as in continental glaciers. Glaciers are immense agents of erosion and landscape modification.

GROUNDWATER Water beneath the surface of the land, consisting largely of surface water that has seeped or permeated downward. May become part of an aquifer, or the source of a spring. Acidic groundwater dissolves calcite in limestone, creating karst.

HABITAT The native environment, or home, of a plant or animal; the kind of place that is natural for the life and growth of an animal or plant.

HETEROTROPHIC Relating to an organism that must feed on organic materials formed by other organisms in order to obtain energy; contrast with autotroph. Includes animals, fungi, and many unicellular organisms.

HIBERNACULA A protective, secure residence, such as a cave or burrow, of an animal that spends time in a dormant condition.

HIBERNATION A period of dormancy or inactivity, varying in length depending on the species, and occurring in dry or cold seasons. Metabolic processes are greatly slowed and body temperatures may drop close to the freezing point.

HOMEOTHERMIC Relating to an organism, such as a bird or mammal, capable of maintaining a stable body temperature independent of the environment.

HUMERUS A bone of the upper arm or limb of an animal.

HYDROLOGY The science dealing with the occurrence, circulation, distribution, properties and effects of the waters of the earth and its atmosphere.

HYPOTHERMIA Life-threatening condition of having a body temperature greatly below normal.

ICE AGE A time of great glacial advance, the last one ending about 10,000 years ago.

IGNEOUS Produced under conditions involving intense heat, as rocks of volcanic origin or rocks crystallized from molten magma.

INTRUSION The forcing of extraneous matter, as molten rock, into some other geologic formation.

INVERTEBRATE An animal lacking a vertebral column, or internal backbone, such as crustaceans, bacteria, plankton, and algae.

ISOSTASY/ISOSTATIC REBOUND Land areas rebounding, or returning to equilibrium, from a period of depression due to an overriding mass of glacial ice, as during the last ice age. Isostatic rebound in southeast Alaska has been found to be anywhere from a few meters to a hundred meters, depending largely on the degree of glaciation at a particular location.

KARST Topography that develops in areas underlain by soluble rocks, primarily limestones. Dissolution of subsurface strata results in areas of well-developed subsurface drainage characterized by sinkholes, collapsed channels, vertical shafts, and caves. The name derived from the Balkan region of Kras, where early karst research was conducted.

LIMESTONE Stone consisting primarily of calcium carbonate. Exoskeletons of many marine organisms contain calcium carbonate. With time, sea floor accumulation, compaction and cementation, these calcite beds become limestone formations.

LITTORAL Pertaining to the shore of a lake, sea, or ocean.

MACROSCOPIC Generally small, but visible and distinct to the unaided eye. Gastropods are macroscopic organisms.

MARITIME Living, situated, or found near the sea or ocean.

MARMOT Bushy-tailed, stocky rodent of the genus *Marmota*, common in northern terrestrial regions.

MEGAFAUNA Referring to large animals, such as caribou, bison, bear, and moose.

MICROCLIMATE The climate of a small or confined area, such as a cave, plant community or wooded area.

MICROSCOPIC Organisms, for example, so small as to be invisible or indistinct without the aid of a microscope. Bacteria are microscopic organisms.

MIDDEN A refuse heap; a pile of discarded waste associated with a human settlement; shell midden. Middens are often rich archaeological sources.

MIGRATION Movement of people or animals from one place or region of habitation to another. Examples are the migration of people from Asia to North America or migration of birds south for the winter. Also refers to plate tectonics and the migration of terranes or microplates.

MONERANS Of the kingdom *Monera*. Prokaryotic bacteria that play an important role as decomposers of organic matter. The most abundant, oldest and smallest organisms in the world; they can survive in many environments that support no other form of life.

MOON MILK A dripstone calcium carbonate deposit or speleothem; accumulates to several feet thick in some southeast Alaska caves, with possible bacterial associations accounting for the depth.

MUSKEG The Alaskan name for a swamp or bog. Characterized by waterlogged soils, impermeable substrate, acidic water and plants such as sphagnum moss and sedges. The acidic water flow from muskegs accelerates development of subsurface karst.

MYCOLOGY The branch of botany dealing with fungi.

NATAL Pertaining to birth. Bears, wolves, and river otters use caves for natal, or birthing, purposes.

OBSIDIAN A volcanic glass similar in composition to granite, usually dark but transparent in thin pieces and having a good conchoidal fracture.

OMNIVORE An animal that consumes both plant and animal foods.

PALEOECOLOGY Study of the ecological relationships prevailing in past geologic ages.

PALEOKARST Karst formations existing for a great period of geologic time. Most caves in southeast Alaska predate the latest glacial advance, with some evidence showing ages of millions of years.

PALEONTOLOGY The science of the forms of life existing in former geologic periods, as represented by fossil animals and plants.

PASSERINE Birds of the order *Passeriformes*, with feet adapted for perching. Includes more than half of all bird species, such as dippers, swallows, and thrush species.

PEATLANDS Otherwise known as muskegs, fens, or bogs. Characterized by waterlogged soils, impermeable substrate, acidic water, and plants such as sphagnum moss and sedges. The acidic water flow from peatlands accelerates development of subsurface karst.

PERMEABILITY Pertaining to a rock or soil and its capacity for transmitting a fluid through its pore spaces.

PHOTOSYNTHESIS Synthesis of complex organic materials, especially carbohydrates, from carbon dioxide, water, and inorganic salts, using sunlight as the source of energy and with the aid of a catalyst such as chlorophyll.

POROSITY The volume of pore space in rock or soil, expressed as a percentage of total volume.

PROKARYOTIC Cells lacking a membrane-bound nucleus and membrane-bound organelles; a bacterium or cyanobacterium.

PROTISTS Of the kingdom *Protista*. Eukaryotic, mostly unicellular organisms, including amoebas, paramecia, and algae.

RADIOCARBON DATING Determination of the age of objects of plant or animal origin by measurement of the radioactivity of their radio-carbon content, which declines at a steady rate over time.

RECHARGE AREA Surface areas that supply water to subsurface karst systems.

REFUGIA/REFUGIUM A place, or places, free or safe from glacial advance, such as a nunatak, or exposed knob of bedrock surrounded by ice.

RELICTUAL Referring to an organism living in an environment different from that which is, or was, typical for it. For example, a population that can no longer live in the surface world due to climatic changes but can persist in more stable cave conditions.

RILL A long, narrow trench; a feature of epikarst terrain.

ROOKERY A colony, or breeding place, most commonly of birds, such as cormorants, pigeon guillemots, murres, and puffins.

SILL An intrusive sheet of igneous rock forced, usually horizontally, between layers of older surrounding rock strata.

SINKHOLE A relatively shallow bowl- or funnel-shaped depressions ranging in diameter from a few feet to more than 3,000 feet. Generally formed by dissolution of and subsequent settlement of bedrock to form a depression, or collapse of shallow cave roofs to form a depression.

SOLUTION The process of chemical weathering by which rock material is dissolved and removed, as in the formation of karst features.

SPELEOGEN Relief features on the walls, ceiling and/or floor of a cave that are part of the surrounding bedrock.

SPELEOLOGY The exploration and study of caves.

SPELEOTHEM Any natural mineral formation or deposit occurring in a cave, including flowstone, helictites, soda straws, and moon milk.

SPRING A surface seepage of groundwater; common in karst landscapes.

SUBSTRATE Underlying stratum or layer, as in bedrock beneath soil.

SUBTERRANEAN Subsurface; below ground level.

STALACTITE Calcium carbonate formation shaped like an icicle, often hanging from the roof of a cave, formed by the dripping of percolating calcareous water.

STALAGMITE Calcium carbonate formation resembling an inverted stalactite, formed on the floor of a cave by the dripping of percolating calcareous water.

STROMATOLITE Reef formation composed of mats of photosynthetic bacteria and sediments.

TECTONIC Relating to forces or conditions within the earth that cause movements of the crust such as earthquakes, folds, or faults. Tectonic forces have caused the accretion of exotic terranes that comprise Southeast Alaska today.

TECTONIC PLATE Large section of the earth's crust, either oceanic or continental, that is in motion due to forces within the earth. Tectonic activity in Alaska is due to interaction between the Pacific plate, and the North American plate.

TERRANE A rock formation or continental plate fragment of lesser density which rides upon an oceanic plate of greater density. It may either join with other fragments, merge with a microplate, or dock with a major continental plate. The terranes of Southeast Alaska have moved from distant regions and are called exotic terranes.

TERRESTRIAL Pertaining to earth or land, as opposed to water or air; things living or growing on, or in, the ground.

THEORY An hypothesis supported to some extent by evidence but not conclusively proven or accepted as a law.

TOPOGRAPHY Physical features of a region, especially the relief and contours of the land.

TROGLOXENE Cave visitor: uses cave habitat for specific purposes, on a sporadic basis, and exhibits no cave-related adaptations.

TROGLOPHILE Cave lovers: have a strong affinity for the dark, moist, and cool conditions of cave interiors and sometimes show changes in their anatomy, physiology, or behavior.

TROGLOBITE Cave dwellers: spend their entire life cycles in the dark zones of caves and exhibit a variety of adaptations to interior cave conditions.

VERTEBRATE An animal having an internal backbone, or spinal column, such as mammals, birds, reptiles, amphibians, and fishes.

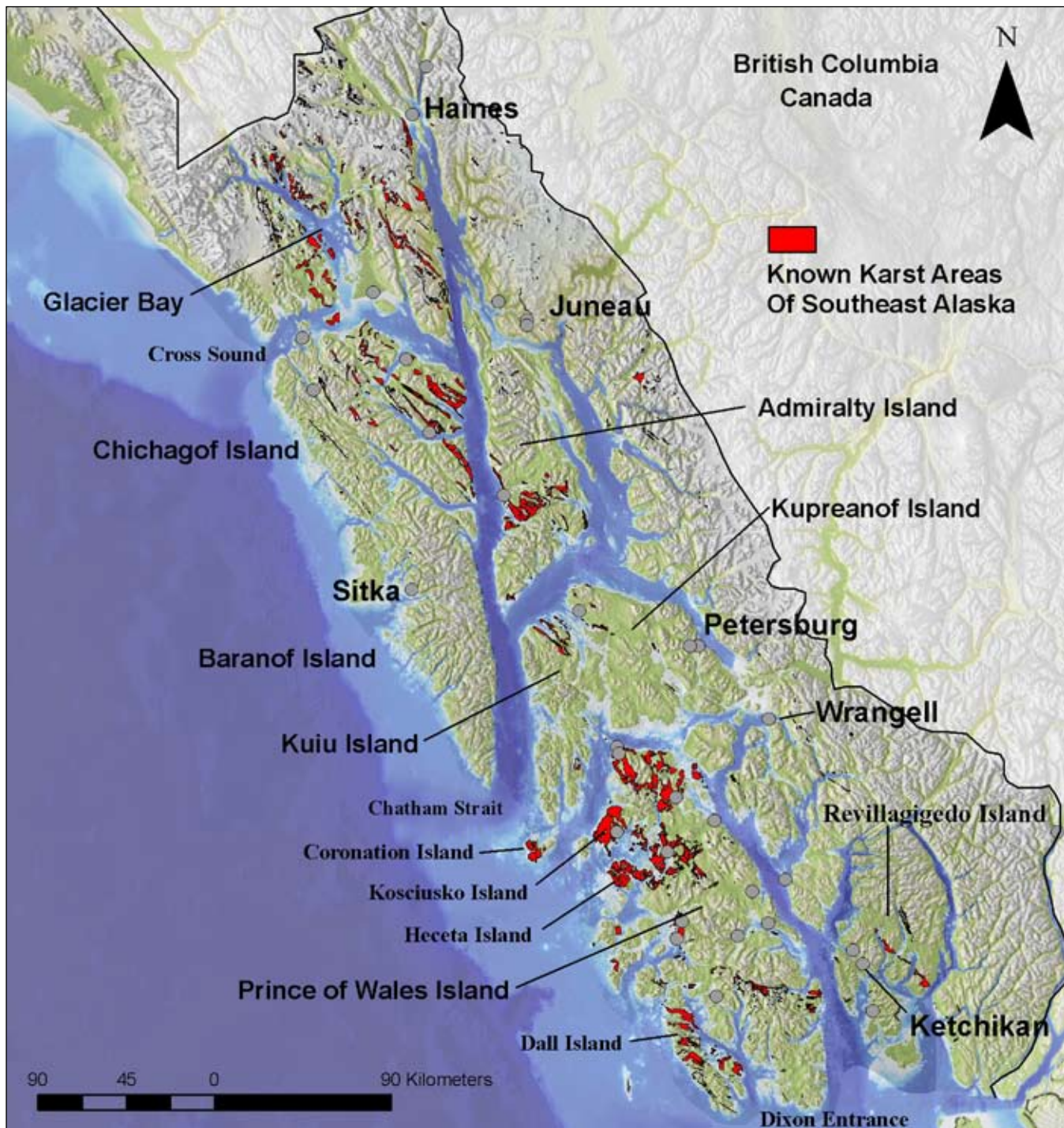
WATERSHED The region drained by a river system; a drainage basin.

WATER TABLE The depth below which the ground is saturated with water; the level of groundwater.

References for glossary

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Map of Karst Areas in Southeast Alaska



ACTIVITIES

Acid Rock

Soda Sink

Milk Jug Hydrology

Dew or Rain?

Soil Communities

Archaeological Site Formation Processes

Archaeological Disturbance Formation Processes

Word Find Puzzle

Crossword Puzzle

ACTIVITY

ACID ROCK

GRADE LEVEL: 7-12

Goal

Carbonate rocks and carbonate-dominated landscapes react to and are sculpted by slightly acidic rainwater.

Objectives

At the end of the laboratory activity, the student should be able to observe the effects of an acid on soluble and insoluble rock types and to understand how the interaction of acidic solutions with soluble bedrock contributes to the formation of caves.

Background

When rain mixes with carbon dioxide in the air, it forms a weak acid called carbonic acid. Thus, the rain entering surface and subsurface waters is slightly acidic. As water percolates through the soil and other subsurface materials, it becomes more acidic. This increasing acidity is due to the release of carbon dioxide into the soil from the respiration of microorganisms and plant root systems. Carbon dioxide is also released from the decay of organic matter. Some of the carbon dioxide which dissolves in the subsurface water reacts with the water, and more carbonic acid is formed. Another source of acidity in the soil is organic acids released from the decay of dead organisms.

If an area is underlain with soluble bedrock, such as the carbonates of limestone or marble, it slowly dissolves when exposed to the acidic groundwater. Cracks and fissures in the rock are natural points of water collection and chemical erosion. Over time, these sites enlarge and a cave is formed.

A standard test to distinguish carbonate from non-carbonate rock is exposure to an acid. Carbonate rocks undergo a “bubbling” chemical reaction when exposed to an acid.

Please note: this activity can also be performed as a demonstration, rather than as individual student or group investigations.

ALASKA STUDENT PERFORMANCE STANDARDS

All Alaskan students will understand scientific facts, concepts, principles and theories.

Students who meet this standard will ...

(7) Understand how the earth changes because of plate tectonics, earthquakes, volcanoes, erosion and deposition, and living things.

(15) Use science to understand and describe the local environment (Local Knowledge).

All Alaskan students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting, and experimenting.

(2) Design and carry out scientific investigation using appropriate instruments.

All Alaskan students will understand the nature and history of science.

Students who meet this standard will ...

(2) Know that scientific knowledge is validated by repeating specific experiments which may conclude in similar results.

Materials

Small beakers
Watch glasses
Wood splints
Eye droppers
Dilute hydrochloric acid
Safety goggles
Lab aprons
Rock samples (both carbonate and non-carbonate rock)
Universal pH papers

Procedure

1. Place each rock sample into a beaker. Put two or three drops of dilute hydrochloric acid on each sample. Observe and record your observation with each sample. Which samples are carbonates?
2. Extension activities
 - a. Place several pieces of limestone in a beaker and add enough dilute hydrochloric acid to cover the rock samples. Cover the beaker with a watch glass. Allow the reaction to take place for at least 30 seconds. Place a burning wooden splint into the beaker. Record your observation. Make a hypothesis based on your observation. For example, what kind of gas is given off in this reaction?
 - b. With universal pH papers, test the acidity of water from different sources—peatland (muskeg) water from different areas, streams flowing from peatlands, streams flowing from caves etc.—and record your results. Consider why the acidity varies.
 - c. Weigh a clean, dry clam shell or a piece of limestone, and record its weight. Place the sample in a glass container of peatland water. Observe the sample for several days. Does the sample change in appearance? Does any bubbling occur? Record your observations. Take the sample out of the solution and carefully dry it. Weigh the sample and record the results. Compare the before and after weights of the sample. Make a hypothesis concerning the reaction. Speculate about the length of time involved in cave formation.

Assessment

1. Theoretical: Examination of photographs from karst landscapes around the world and determination of the similarities and differences among them.
2. Theoretical: Extension of knowledge about acidic rainwater in other contexts, such as forested muskegs and ages of trees.
3. Practical: Examination of pH of individual home water systems and individual tolerances for drinking water.

ACTIVITY

SODA SINK

GRADE LEVEL: 5-8

Goal

Water that enters the surface of the ground becomes available to act dynamically in a recharge system that is influenced by soluble and insoluble bedrock.

Objectives

At the end of the laboratory activity, students should be able to perform an investigation that will help them to conceptualize the difference between discrete and diffuse recharge and to understand the difference between soluble and insoluble bedrock and how bedrock composition influences subsurface water flow.

Background

The place where rain or surface water enters the ground and becomes part of the groundwater is called a recharge location. In karst areas, where the ground is underlain by soluble bedrock, the soil is thin and groundwater moves quickly through sinkholes, caves and springs. A sinkhole is a rounded depression on the land's surface where water funnels soil and dissolved rock particles into underlying cracks and caverns. Because karst groundwater flows through actual openings in the rock, it is often poorly filtered. This type of groundwater flow is called discrete recharge. Groundwater in discrete recharge systems may move at rates that are measured in feet per minute.

In places where the earth is underlain by thick layers of soil or slowly decaying vegetation (peatlands), groundwater moves very slowly and more filtration occurs. This is called diffuse recharge. Groundwater in diffuse recharge systems may move slowly—at a rate measured in inches per year.

By constructing models of both types of recharge systems, students will investigate rates of water flow and each system's susceptibility to pollution.

Please note: this activity can also be performed as a demonstration, rather than as individual student or group investigations.

ALASKAN STUDENT PERFORMANCE STANDARDS

All Alaskan students will understand scientific facts, concepts, principles, and theories.

Students who meet this standard will ...

(7) Understand how the earth changes because of plate tectonics, earthquakes, volcanoes, erosion and deposition, and living things.

(15) Use science to understand and describe the local environment (Local Knowledge).

All Alaskan students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting, and experimenting.

(2) Design and carry out scientific investigation using appropriate instruments.

All Alaskan students will understand the nature and history of science.

Students who meet this standard will ...

(2) Know that scientific knowledge is validated by repeating specific experiments which may conclude in similar results.

Materials (to construct one set of three models)

6 two-liter plastic soda bottles (remove labels)	Tomato juice
Gravel rocks ($\frac{1}{2}$ inch to 1 inch in diameter)	Scissors
Soil	Soda straw
Measuring cup	Small buckets
Water	

Procedure

1. Assemble models: Cut the bottom off three soda bottles two inches down. Cut the top off the remaining three soda bottles three inches down. Turn the top soda sections upside down and insert them into the bottom sections. These will be the three groundwater models.
2. Label the three models A, B, and C.
3. Pour gravel into the top half of model A until it is half full.
4. Pour gravel into the top half of model B until it measures one inch. Cover the gravel with four inches of soil.
5. Insert a soda straw through the pour spout of the top bottle of model C. Pour gravel into the top half of model C until it measures four inches. Make sure the top of the straw is approximately even with the level of the gravel. The gravel will hold the soda straw in place. Place three inches of soil over the gravel and top of the soda straw.
6. The three groundwater models are now complete.
Model A: discrete recharge system. Water flows through the cracks and fissures between rocks.
Model B: diffuse recharge system. Water filters through soil particles.
Model C: combination of both diffuse and discrete recharge with a cave through the rock units. This gives ideal conditions for a sinkhole to form.
7. Give each student a copy of the results and conclusions sheet for the soda sink activity. Ask students to make predictions about groundwater flow through each model. Remind them to time the flow of water in each model.
8. Measure equal amounts of water and pour the water slowly into the center of each model. (Model C may require more water for the sinkhole to form.) Students should observe and record scientific observations on the results and conclusions sheet.
9. Add “contaminated” water. Measure equal amounts of tomato juice and water, mix and pour slowly into the center of each model. Have students observe and record observations on the activity sheet.
10. As an extension, test the models using other materials such as Kool-Aid mix to simulate contamination.

Results and Conclusions: Soda Sink

1. Record observations from groundwater demonstration. Note the color of the water after it flows through the model and the length of time it took the water to percolate.

	Model A	Model B	Model C
Water	_____	_____	_____
Tomato Juice	_____	_____	_____

2. How does diffuse recharge differ from discrete recharge in the models?

3. In which models is water more susceptible to groundwater contamination? Why?

Assessment

1. Theoretical: Using tracer dyes allows a variety of conditions to be simulated. Predict which re-charge systems are at work after field visits.
2. Practical: Determine whether point source pollution affects the karst landscape in your commu-nity and suggest a solution to the issue.

ALASKA STUDENT PERFORMANCE STANDARDS

All Alaska students will understand scientific facts, concepts, principles, and theories.

Students who meet this standard will ...

(7) Understand the earth changes because of plate tectonics, earthquakes, volcanoes, erosion, deposition, and living things (Processes that Shape the Earth).

(15) Use science to understand and describe the local environment (Local Knowledge).

All Alaska students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting and experimenting.

(2) Design and carry out scientific investigations using appropriate instruments.

(3) Understand that scientific inquiry often involves different ways of thinking, curiosity and exploration of multiply paths.

(4) Understand that personal integrity, skepticism, openness to new ideas, creativity, collaborative effort and logical reasoning are all aspects of scientific inquiry.

ACTIVITY

MILK JUG HYDROLOGY

GRADE LEVEL: 7-12

Goal

Water that flows beneath the surface plays an active role in cave formation, expansion and the transportation of pollutants.

Objectives

At the end of the laboratory activity, the student should: understand the complexity of subsurface water flow patterns in cave systems; understand how flood waters expand cave systems; and understand how pollutants can migrate through cave systems.

Background

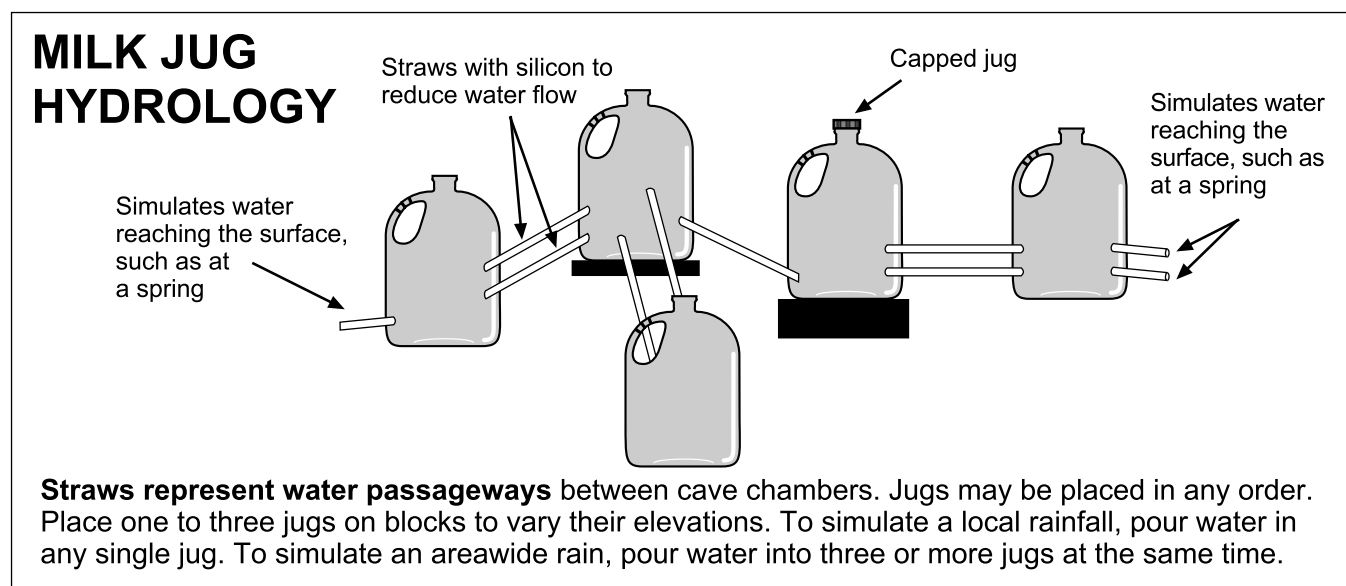
Scientists who study caves believe that limestone caves develop as water slowly flows through the region below the water table. The water table refers to the level below which the substrate is saturated with water. Subsurface water movement is extremely slow, except in a thin zone immediately below the water table. This narrow layer is the area where most limestone caves form. Thus, the level of the water table is important because its horizontal character establishes the depth at which many cave systems develop. Cave passages begin as small fractures in the limestone bedrock below the water table, and gradually enlarge as the acidic water collects in the joints and dissolves the calcite in the limestone. Over thousands of years, the conduits form an interconnecting network of passages and chambers. Throughout this process, cave hydrology is greatly influenced by local and regional precipitation, especially in an area such as southeast Alaska, with its great amount of annual rainfall.

Materials

5 one-gallon plastic milk jugs and 4 gallons of water
1 box of straws with bendable necks
Small electric drill and $\frac{3}{16}$ -inch bit
1 tube of silicon caulk or Permatex
4 or 5 books or blocks of wood for elevation
Large pitcher
Food coloring

Procedure

1. Select 10 straws and place some silicon caulk in each to slow the flow of water. (Do not stop the flow, just reduce the amount to about half or less.) This step must be done early so that the caulk will have time to dry.
2. Exact placement of the holes and straws is required. The two end jugs (1 and 5) will have fewer holes and straws than the three jugs situated between the outside two. *Use the diagram as a guide for placement of the jugs and straws.*
 - a. Jug 1 should have one of the silicon straws sticking out, away from the rest. This straw should be in the middle of the outside and about 2 inches from the bottom.
 - b. Rotate jug 1 by 180 degrees to the side opposite the first straw. This side will have two straws, one a little above the first. Drill the first hole near the center, (left to right), about 2½ inches from the bottom. Drill the second hole about 2½ inches above the first hole, slightly to the left or right
 - c. Place the third jug on a book or block to elevate it, and slide the unit up close to the second jug so that the straws which were placed in the second will come in contact with the third jug. Level the straws sticking out of the second jug, and drill a hole where they come in contact with this jug.
 - d. Continue the same process with the next two jugs. Be careful to vary the height of the other connections, and the use of the block or book for elevations. Do *not* drill any holes above half the height of the jug.
3. After the jugs are connected with the straws, place a small bead of silicon around each straw at the hole to prevent it from leaking.
4. After the silicon has had several hours to dry, take a pitcher of water and pour it into one of the end jugs to simulate the effect of a local rain storm on one end of the cave system. Students should observe how and when each “jug cavern” fills, and record their observations in the Results section #1.



5. Water may be added to each of the containers, or just the three middle ones, to simulate the effect of a hard regional rain. (Note that flood waters such as this do the most to expand the cave system rapidly.) Students should again observe the filling pattern, and record their observations in the Results section #2.

6. Extension Activity: What occurs when waters of different temperatures are added to the cave system? Try these variations.

a. Add about a half-gallon of warm water, colored with a food coloring, to each end of the jug system, only after the four gallons of water have been introduced to the system. Observe and record in the Results section #5. a.

b. Add about a half-gallon of warm water, colored with a food coloring, to the middle-most jug, after the four gallons of water have been introduced to the system. Observe and record in the Results section #5. b.

c. At the same time, add about a half-gallon of warm water, colored red, to one end of the system, and a half-gallon of ice water, colored green, to the other end of the system. Observe and record in the Results section #5.c.

Results and Conclusions — Milk Jug Hydrology

1. Describe the simulated effect of a local rain storm on the cave system.

2. Describe the simulated effect of a regional rain storm on the cave system.

3. What conclusions can you draw concerning the influence of storm events on cave systems?

4.a. What is the relationship between points of water injection into the system and points of discharge, such as springs?

4.b. What is the implication of this situation with regard to pollutants and cave systems?

5. What influence does water of different temperatures have on the cave system and its hydrological processes?

5.a. _____

5.b. _____

5.c. _____

Assessment

1. Theoretical: Create a milk jug model to describe a local cave and its dynamic to a younger audience.

2. Practical: Visit the same cave after a storm event and simulate it with a jug model to help explain the stabilizing conditions of the ground surface and vegetation.

ALASKAN STUDENT PERFORMANCE STANDARDS

All Alaskan students will understand scientific facts, concepts, principles and theories.

Students who meet this standard will ...

(4) Understand observable natural events such as tides, weather, seasons and moon phases in terms of the structure and motion of the earth (Earth).

(15) Use science to understand and describe the local environment (Local Knowledge).

All Alaskan students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting and experimenting.

(2) Design and carry out scientific investigation using appropriate instruments.

All Alaskan students will understand the nature and history of science.

Students who meet this standard will ...

(2) Know that scientific knowledge is validated by repeating specific experiments which may conclude in similar results.

ACTIVITY

DEW OR RAIN?

GRADE LEVEL: 5-8

Goal

Outline the role of condensation in the water cycle and the role that weather plays in karst landscapes and associated ecosystems.

Objectives

At the end of the laboratory activity, the student should be able to: understand the factors underlying the process of condensation; understand how and when dew forms; understand how the dew point is measured; understand the relationship between dew and rain formation.

Background

Condensation is the changing of a gas (vapor) to a liquid state. This change can be triggered by a drop in temperature: for example, when water vapor in the air condenses as dew. Warm air holds more water vapor than cool air, so that as the air cools, it becomes saturated, and the relative humidity reaches 100 percent. As air cools beyond the saturation point, water vapor begins to condense on surfaces. The temperature at which the air is saturated is known as the dew point, and the water that condenses below that is called dew. (The following activity is designed for groups of three students.)

Materials

Each group of three students will need:

A metal can
A thermometer
Ice cubes
A stirring rod
Water at room temperature
A beaker
3 balloons
A piece of aluminum foil

Procedure

1. Introduce this activity by discussing weather, the water cycle, condensation and surface tension.
2. As a preliminary activity, have students blow into the air and ask them what they see (usually nothing). Have them breathe on a piece of aluminum foil or a mirror. They should see some mist on the mirror or foil. Now have the students blow up balloons and ask them what is happening and what is collected in the balloon. If students understand that air can be collected, it will be easier for them to grasp the concept that air holds water vapor that can be collected. Students should continue to observe the water droplets on the foil or mirror. Discuss how this moisture got on the surface of these items and why it remains on the surface.
3. For the main activity, open a discussion with the following questions. Where does the water from the ocean go when it evaporates? Where does the water from a bathtub or shower go when it evaporates? Where does the water on plants, cars, and houses that we see in the early morning come from? What type of temperature change must occur before condensation or dew forms? Finally, ask them what they think the dew point is.
4. Now, fill the can half full with water. Add four to six ice cubes to the water, stir and put the thermometer into the water.
5. To see the condensation when it is first forming, continually wipe the side of the can with your finger until you feel moisture or you see a path left by your finger through the condensation forming on the outside of the can. When you first notice the condensation, quickly measure the temperature and write it down. This temperature is very close to the dew point.
6. All groups in one room will usually get temperature readings very close to each other. After seeing condensation form on the cans, students should be able to visualize how dew forms in our environment. Be sure they do not form the impression that the vapors penetrated to the outside of the can. Emphasize that condensation on the can came from water vapor in the air around the can.
7. Have each group read their dew points to the class. Explain that both the temperatures of the surrounding air (which varies around the room) and the temperature of the ice water affect the dew point.
8. Finally, ask students what they think happens to dew when the temperature continues to drop. From their observations of this activity, can they guess how rain forms?

Assessment

1. Theoretical: Determine the factors that influence condensation in differing climatic zones, including the continental edge in Southeast Alaska.
2. Practical: Assess the level of rainfall in karst landscapes by comparing weather station gauges and field runoff tests.

*(Based on an activity from **Water, Stones, and Fossil Bones**. Permission granted for reproduction for the purpose of classroom or workshop instruction.)*

ALASKA STUDENT PERFORMANCE STANDARDS

All Alaska students will understand scientific facts, concepts, principles, and theories.

Students who meet this standard will ...

(9) Know about the transfers and transformations of matter and energy that link living things and their physical environment, from molecules to ecosystems (Flow of Matter and Energy).

(12) Distinguish the patterns of similarity and differences in the living world in order to understand the diversity of life. Understand the theories that describe the importance of diversity for species and ecosystems (Diversity).

(14) Understand the interdependence between living things and their environment. Know that the living environment consists of individuals, populations, and communities. Recognize that a small change in a part of the environment may affect the whole (Interdependence).

(15) Use science to understand and describe the local environment (Local Knowledge).

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ACTIVITY

SOIL COMMUNITIES

GRADE LEVEL: 7-12

Goal

Soil is a combination of living organisms, minerals and decaying organisms.

Objectives

At the end of the laboratory activity, students should be able to: describe the operation of the Berlese funnel; name the major groups of cryptozoan organisms that inhabit soil communities; compare the cryptozoan populations of several different sites; and offer an explanation for any differences in population size and species composition.

Background

Soil is a complicated and variable mixture of living organisms and nonliving matter. Soil composition varies greatly among different terrestrial ecosystems. Organisms which live in soil are called cryptozoa and form underground microcommunities. Certain physical conditions of soil are similar to those of cave environments, such as a lack of sunlight. Thus, studying soil organisms helps our understanding of small cave organisms. Indeed, research in karst areas has indicated that some cave systems host relic invertebrates, representative of soil fauna from past geologic and climatic conditions.

Because sunlight does not penetrate into soil, the dark environment does not support photosynthetic organisms. However, dead organic material is constantly deposited on and in soil, which provides a rich source of nutrients for soil organisms. Bacteria, other microorganisms and small invertebrates feed on this matter, called detritus, and extract the remaining energy from the organic debris. The decomposers may, in turn, be consumed by small predators. Eventually, dead soil inhabitants also become part of the detritus. When no more energy can be removed from the organic material it is called humus, which is also an important part of soil.

Materials

Coffee can, 10 cm diameter (or other suitable container)

Trowel

Plastic bag

Marking pencil or pen

Gummed labels

Large tray

Forceps

Isopropyl alcohol (rubbing alcohol) with glycerin

Cheesecloth

Berlese funnel apparatus

Light source

Collecting vials

Dissecting microscope

Watch glass

Dissecting needles or fine brush

Identification Guides for Invertebrates

Procedure

Field Collection

Due to the fragile cave environment, do not select caves as one of the sampling sites. Rather, select several above-ground sites for collection. Choose different environments which support different biological communities. For example, contrast the forest edge environment with the deep forest environment; or contrast an open habitat with a forested habitat; or compare all these environments. Then choose three to five locations within each site for collecting samples.

1. Describe the sites in Question 1 of the Evaluation.

2. Collect soil samples in a coffee can. Push it into the soil to a depth of 5-6 cm. Use a trowel to dig out the soil and place the soil in a plastic bag for transport to the classroom. Include the litter—the loose organic material on the surface of the soil.

3. Label the bags with the date, collection site, location and name of student. Samples may be stored in the refrigerator for a week, if necessary.

All Alaskan students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting and experimenting.

(2) Design and carry out scientific investigations using appropriate instruments.

(3) Understand that scientific inquiry often involves different ways of thinking, curiosity and exploration of multiple paths.

(5) Employ ethical standards, such as unbiased data collection and factual reporting of results.

All Alaska students will understand the nature and history of science.

Students who meet this standard will ...

(2) Know that scientific knowledge is validated by repeating specific experiments which may conclude in similar results.

In the Classroom

1. Spread the contents of the bag from each site on a large tray. Using a pair of forceps, remove the larger organisms and place them in a jar of isopropyl alcohol with several drops of glycerin. If the soil is particularly wet, allow it to dry until it is crumbly but not totally dry.
2. To separate the smaller organisms from the soil, place the sample inside the Berlese funnel.
3. Place the collecting vial, containing isopropyl alcohol, under the funnel. Place a light source several centimeters above the sample to drive the organisms into the collecting vial. Allow one or two days for collecting. Check for evaporation of the alcohol and replace alcohol as needed.
4. Repeat for each site. Use a separate collecting vial for each site.
5. After collecting the specimens, classify them into “look-alike” groups. Use a dissecting microscope to aid the classification process. Place the sample of organisms in a watch glass and use dissecting needles or a fine brush to sort them into groups according to their structures.
6. Identify each group with a letter or number. Sketch a representative from each group. Count the number of individuals in each group. Record this information in Question 2 of the Evaluation.
7. As an extension for older students, use animal identification keys to classify the organisms into major taxonomic groups, such as *Arachnida* (spiders), *Insecta* (insects), *Chilopoda* (centipedes), *Diplopoda* (millipedes) and *Crustacea* (crustaceans).

Results and Conclusions: Soil Communities

On the following evaluation form, record the results of the exercise in parts 1 and 2, and respond to part 3 for the conclusion.

Part 1: Description of Sites

Describe the sites used for this investigation and the reason for selecting these areas.

Description

Reason for Selection

Site #1

Site #2

Site #3

Site #4

Site #5

Part 2: Organism Identification

In the space below, sketch a representative organism from each group in each site studied and note the total number collected.

Part 3: Site Comparison

Compare each site with regard to population size and type of organisms found. What does this indicate about the different terrestrial communities? _____

Assessment

1. Theoretical: Determine the biodiversity at the cave site with a non-invasive technique inventorying organisms.
2. Practical: Apply the adaptations of cryptozoan organisms in soil to cave organisms and write a Leave No Trace ethics booklet for local caves.

ACTIVITY

ARCHAEOLOGICAL SITE FORMATION PROCESSES

GRADE LEVEL: 7-12

Goal

Sites are created over time through disturbance of the natural landscape by human processes (digging, creating middens, making fires) and natural processes (flooding, erosion, cave spalling) and the sites have characteristic stratigraphic and non-stratigraphic profiles.

Objectives

At the end of this activity, students should be able to: identify site formation processes; identify specific agents of change affecting site composition; describe accurately and clearly the possible effects of each site change agent; and record their observations.

Background

The idea is to start with a simple campsite, just abandoned by its former inhabitants. The campsite may have been occupied by modern campers or by a group of prehistoric hunters long ago. We want to show how the campsite with all its features and artifacts in place is transformed by various agents (plants, animals, water, soil chemistry, later people) into the archaeological site that the archaeologist finds today. And we want to think about how we use the archaeological evidence to build a picture of past cultures.

Materials

Rocks for a hearth site or campfire
Modern camping debris such as a tent stake, tin can lid, plastic bottles, cartons, plastic wrap
Deer or other animal bones

Alternate materials—Campsite debris from early peoples, such as:
Stone tools
Debitage (discard from stone tool manufacturers)
Animal bones
Remains of wooden implements

ALASKA STUDENT PERFORMANCE STANDARDS

All Alaska students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science; including observing; classifying; measuring; interpreting data; inferring; communicating; controlling variables; developing models and theories; hypothesizing; predicting and experimenting.

(2) Design and carry out scientific investigations using appropriate instruments.

(3) Understand that scientific inquiry often involves different ways of thinking, curiosity and the exploration of multiple paths.

(4) Understand that personal integrity, skepticism, openness to new ideas, creativity, collaborative effort and logical reasoning are all aspects of scientific inquiry.

(5) Employ ethical standards, such as unbiased data collection and factual reporting of results.

(6) Employ strict adherence to safety procedures in conducting scientific investigations.

All Alaska students will understand the nature and history of science.

Students who meet this standard will ...

(6) Understand that scientific discovery is often a combination of an accidental happening and observation by a knowledgeable person with an open mind.

Procedure

1. Students divide into work groups and each group designs a campsite, including its features and artifacts.
2. Students write descriptions of the inhabitants and their activities.
3. Students then build replicas of their group campsites.
4. Each student takes a role in modifying the campsite. For example, one will be a bear, another a windstorm, etc.
5. Students go to the site and take away or move things, according to their roles.
6. Students in pairs or trios then visit each site and carefully record the site, using measurements, illustrations and a narrative.
7. Each group should meet and discuss each site, including:
 - a. The original inhabitants and their activities.
 - b. Agents (natural and human) that modified the site and the effects of these agents.
8. Every group writes up their scenario for each site.
9. A class discussion should focus on describing realistic possibilities and on why some scenarios are more likely than others, based on the evidence provided.

Results and conclusions

All students should hand in descriptions of their own sites, their roles in altering it and the impacts of change processes on the final conditions of the site.

Each group should hand in an analysis of each site. Each member of every group should be responsible for a section of the report, utilizing input from group members.

Assessment

1. Theoretical: Determine the human behaviors and their artifactual correlates that can be applied to past events as they related to cave use.
2. Practical: Examine your own material cultural world (garbage, antiques, embellishment) and determine what will be left for future archaeologists to propose behavioral theories. What behaviors don't leave behind tangible clues?

ACTIVITY

ARCHAEOLOGICAL SITE DISTURBANCE PROCESSES

Grade Level 7-12

Goal

Sites are created over time through disturbance of the natural landscape by human processes (digging, creating middens, making fires) and natural processes (flooding, erosion, cave spalling) and the sites have characteristic stratigraphic and non-stratigraphic profiles.

Objectives

At the end of this activity, the student should be able to: identify site-altering disturbance processes, and record and discuss observations.

Background

Disturbance processes are mechanical and chemical factors that change the context of the archaeological record and affect the way the locations and condition of artifacts and features are interpreted by archaeologists. Some disturbance processes are animal burrowing; tree root growth; freezing and thawing of water in the sediments; and movement of sediments and artifacts by running water. This exercise provides an example of simulated floralturbation. Floralturbation is the disturbance caused by plants. In this activity, we study the disturbance caused by the growth of tree roots and treefall.

Materials

Cardboard tube
Construction paper
Aluminum foil
Cardboard disk
Box
Flour
Soil

ALASKA STUDENT PERFORMANCE STANDARDS

All Alaska students will understand and develop the skills of scientific inquiry.

Students who meet this standard will ...

(1) Use the processes of science, including observing; classifying; measuring; interpreting data; inferring; communicating; controlling variables; developing models and theories; hypothesizing, predicting; and experimenting.

(2) Design and carry out scientific investigations using appropriate instruments.

(3) Understand that scientific inquiry often involves different ways of thinking, curiosity and the exploration of multiple paths.

(4) Understand that personal integrity, skepticism, openness to new ideas, creativity, collaborative effort and logical reasoning are all aspects of scientific inquiry.

(5) Employ ethical standards, such as unbiased data collection and factual reporting of results.

(6) Employ strict adherence to safety procedures in conducting scientific investigations.

Procedure

1. Construct a scale model of a tree with its root wad. Use common materials such as a cardboard tube, construction paper and tin foil. Attach some form of disk at the base of the tree to represent the root wad.
2. Provide a box or contained surface to plant the tree.
3. Using alternating layers of dirt and flour, cover the root wad of the tree with layers of soil and flour. Flour represents midden from a habitation site.
4. Place artifacts both within the layer and on the surface of the soil layers.
5. Observe what happens when the tree topples.
6. Record all observations made by students regarding the changes in layering, and the positioning of the artifacts.
7. Discuss students' observations regarding the impact of the *floralturbation process* on archaeological investigation.

Results and Conclusions

All students should describe in writing, with illustrations as appropriate, their observations regarding the site before and after the site disturbance—i.e., before *floralturbation*. Students should describe the impact this process may have on archaeological analysis of this site.

Variation

Select several groups of students to be the inhabitants of a site over several different time periods. Let each group successively deposit midden until the root wad is covered. Ask the students to pictorially record the placement of artifacts and midden as it occurs. Challenge the last group, who did not watch the layering occur, to successfully recreate their own pictorial version of the layering process, midden deposits, and artifact placements during an archaeological excavation. Compare the pictures from before and after *floralturbation*.

Assessment

1. Theoretical: Determine the human behaviors and their artifactual correlates that can be applied to past events as they related to cave use.
2. Practical: Examine your own material cultural world (garbage, antiques, embellishment) and determine what will be left to help future archaeologists to propose behavioral theories. What behaviors don't leave behind tangible clues?

CAVE & KARST LANDSCAPE **WORD FIND**

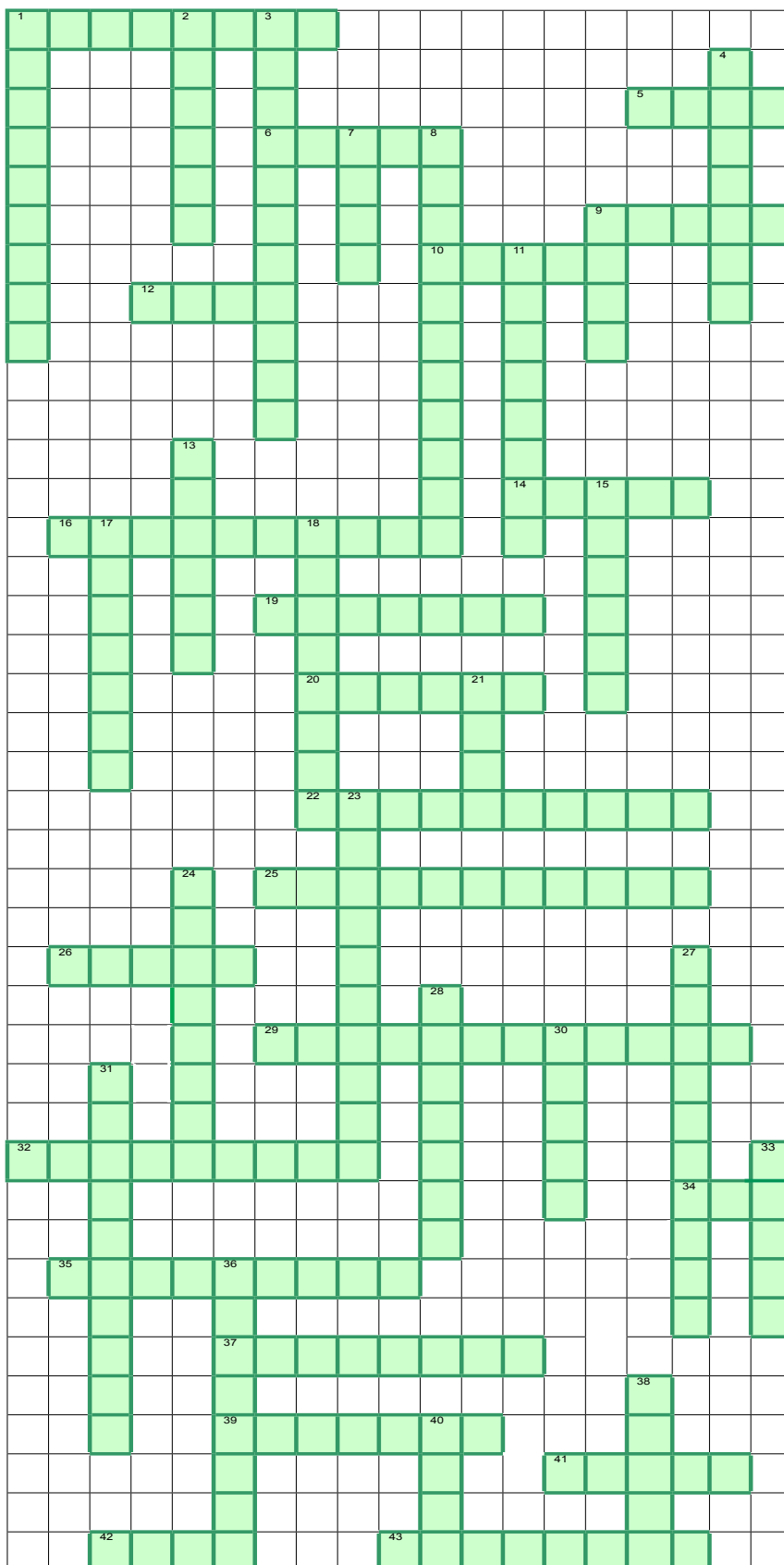
We've hidden 35 words that are related to El Capitan Cave on Prince of Wales Island or to karst landscapes and life forms in this area. The hidden words read right to left, left to right, upward, downward and diagonally. Can you find 35 hidden cave and karst landscapes words?

S	M	U	S	K	E	G	S	E	I	R	R	E	B	C
R	I	V	E	R	B	E	D	A	K	S	A	L	U	U
I	S	T	A	L	A	C	T	I	T	E	A	L	L	B
V	T	I	F	N	A	T	I	P	A	C	L	E	C	C
E	A	L	T	N	R	E	F	D	L	E	I	H	S	B
R	L	A	R	K	C	A	L	C	I	U	M	L	L	E
O	A	D	O	G	A	S	I	R	F	O	N	A	I	A
T	G	Y	G	K	V	S	C	L	U	B	M	R	V	R
T	M	F	L	W	E	T	P	T	N	B	U	T	E	T
E	I	E	O	C	R	Z	Y	R	A	A	L	F	D	I
R	T	R	P	U	N	E	E	T	U	T	O	A	I	F
P	E	N	H	K	S	A	E	V	A	C	C	T	K	A
T	R	O	I	A	R	U	A	N	M	U	E	O	E	C
R	E	T	L	H	E	M	L	O	C	K	A	R	S	T
O	F	E	E	G	A	B	B	A	C	K	N	U	K	S
G	E	P	O	W	V	Q	A	F	E	R	N	T	W	W
L	N	I	D	T	V	N	Y	T	U	N	M	O	R	A
O	O	K	A	N	I	A	R	A	S	I	R	N	E	R
B	T	A	E	T	I	M	L	E	T	D	T	G	I	T
I	S	R	T	C	M	A	A	E	F	M	I	A	E	S
T	W	S	R	N	S	A	N	E	N	R	U	S	F	A
E	O	T	A	K	I	R	R	A	T	B	E	S	D	D
B	L	R	A	H	O	N	A	U	G	J	I	E	A	O
D	F	T	R	O	G	L	O	X	E	N	E	T	D	S

Hidden-word list on page 116

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CAVE & KARST LANDSCAPE **CROSSWORD**



ACROSS

1. Limestone's skin layer
5. Fossils of these found in P.O.W. caves
6. P.O.W. caves are made of this
9. _____ tectonics
10. Bat poop
12. Otter evidence on gate
14. River _____ use caves in winter
16. Ceiling hanging feature
19. 1 of 2 things removable from El Cap
20. Another name for a pool of water
22. Type of fault line in the cave
25. Another name for the twilight zone
26. No remains of this species in El Cap
29. Winter den site
32. Abundant calcified limestone in cave
34. Opposite of dry; S.E. Alaska is very ____
35. Small stalactites filled with calcium
37. Old dead tree on the forest floor
39. S.E. Alaska's most abundant tree
41. Bear's _____; a fungus on trees
42. Cave _____; a troglobyte
43. We use to light our way in the cave

DOWN

1. Alaska's largest known cave
2. State in which El Cap is located
3. Alaska state tree
4. El _____
7. Liquid precipitation
8. Part-time cave dwellers
9. Initials of island El Cap's on
11. Cave invertebrate; i.e., cave shrimp
13. Stalactite + Stalagmite =
15. No taste buds on the cave version
17. America's largest national forest
18. This feature is not 'identical'
21. Peek
23. Perennial cave dweller
24. Cave _____; we joke we can fund cave tours with these.
27. Green _____; a calciphile
28. This isn't 'hung' in the cave like our domestic version.
30. 'Yellow' type stairway made of
31. 'New' visitors to the cave
33. Lime _____; 96% pure in El Cap
36. An opening in the karst surface
38. _____ Room; El Cap control room
40. A subterranean feature; El Cap

Crossword answers on page 116

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With Moe McGee and Jennifer MacDonald